Study on Pseudocomponent Selection & EOS Characterization Influence on Miscibility Pressure

by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Petroleum Engineering)

JANUARY 2011

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Petroleum Engineering Programme
Universiti Teknologi PETRONAS

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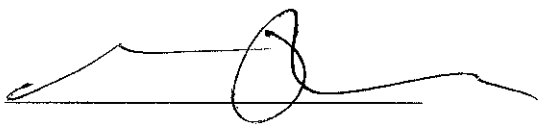
Approved by,



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UNIVERSITI TEKNOLOGI PETRONAS
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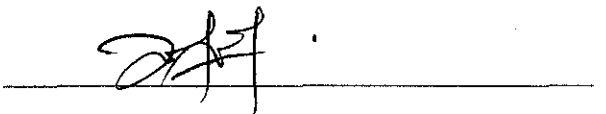
January 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



NUR HAZWANI IZYAN BINTI HASHIM

ABSTRACT

In oil and gas industry, especially exploration and production phase, the main concern is to produce as much oil from the reservoir as possible, which is by optimizing the oil recovery. Since only 20-40% of the total oil in place can be recovered naturally and through pressure lifting, thus enhanced oil recovery (EOR) should be employed to increase the recovery. One of the methods is by miscible injection of gas.

Minimum miscible pressure (MMP) is the pressure at which injection gas mixes with oil, so that oil becomes more mobile and easily moved out from the reservoir. Some factors that affect the value of MMP are the number of pseudocomponent that is used in simulating the reservoir, and also type of Equation of State (EOS) that is used to characterize the reservoir. Therefore, the main outcome of this study is to see how MMP is dependent on the selection of number of pseudocomponent and EOS characterization.

The scope of study of this project would be mainly on reservoir field, with specification on miscibility pressure for EOR. This includes gathering information and literature study on MMP, EOS characteristics and also pseudocomponents properties, familiarization to the software used, simulation using the software, and also result analysis based on the output from the simulation. At the end of the day, the outcome from the simulations would be evaluated to see how these two factors influenced the MMP results.

ACKNOWLEDGEMENT

I would like to take this opportunity to express my utmost gratitude to the persons who have given contributions of time and efforts in assisting me to complete this project. Without their cooperation, I might not be able to make it through.

First of all, special thanks to Mr Iskandar Bin Dzulkarnain, my supervisor, who has been a source of inspiration and backbone throughout the project. His ideas, opinions, advices and useful guidance were always kept me on the track in achieving the objectives of this project.

Not to forget, special thanks to FYP 2 coordinators, Ms Mazuin Jasamai and Dr. Sonny Irawan, in their continuous efforts to ensure that this project stays on the track and within the time frame.

Also, I would also like to express thousands of thanks to my parents and friends, for their incessant moral supports and motivational thoughts throughout this project. Last but not least, to all individuals who have helped me in any way, I would like to thanks to all of you.

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CHAPTER 1

PROJECT BACKGROUND

1.1 BACKGROUND OF STUDY

In oil and gas industry, especially exploration and production phase, the main concern is to produce as much oil from the reservoir as possible, which is by optimizing the oil recovery. Since only 20-40% of the total oil in place can be recovered naturally and through pressure lifting, thus enhanced oil recovery (EOR) should be employed to increase the recovery. The objective of EOR is to 'sweep out' the oil left by conventional methods from the reservoir. One of the methods is by miscible injection of gas. For this method, a good estimation of miscible pressure should be determined before the execution of the EOR job. This is important to ensure the effectiveness of the method and also so that the good reservoir condition will not be disturbed.

At sufficiently high injection pressure, injection gases become miscible with crude-oil and are capable of displacing petroleum fluids from a porous-rock matrix with high efficiency for enhanced oil recovery purposes (Johnson et al., 1981). The main outcome of this study is to see how minimum miscibility pressure (MMP) is dependent on the selection of number of pseudocomponent and EOS characterization. MMP represents the optimum field operating pressure during tertiary oil recovery processes, and it is also dependent upon the composition of the injected gas, reservoir temperature and also the characteristics of the in-place fluids.

Yuan et al. (2004) describe that there are few ways to estimate the MMP, which are by calculation, correlation, simulation or experiment. Since experiment (slim-tube) to predict MMP is time consuming, thus it is always preferred to perform more realistic and accurate analytical calculation, or simulation to estimate the MMP. From this study, we not only can estimate the MMP, but also can show on how MMP estimates made by simulation method can differ significantly for different EOS characterizations and pseudocomponent selection.

An equation of state (EOS) is an analytical expression relating the pressures, p, to the temperature, T, and the volume, V, of a system (Tarek Ahmed, 1991). For physical states of matter, this equation usually relates those three thermodynamic variables; P, V, T, and number of atoms to one another. In reservoir field of study, EOS is not a unique representation of PVT behavior against which it is tuned (Stalkup and Yuan, 2005). There are two ways to predict this MMP with EOS, either by slim-tube simulations or analytically. Two EOS with different parameters may give different simulated recovery or analytical predictions of MMP. By doing this study, the best EOS characterization for MMP can be modeled for better EOR performance.

Newley and Merrill Jr. (1991) stated that EOS model can gives accurate phase–behavior predictions, provided that sufficient components are included to model the systems. For compositional reservoir simulation however, the number of components must be minimized to reduce cost by minimizing the simulation time. Thus, extensive effort has been done to group the extended components distribution into pseudocomponents. For this study, the optimum pseudocomponent number used to predict MMP will be determined in order to reduce the simulation cost and time, while in the same time give best result of predicting miscibility pressure that can enhance recovery.

1.2 PROBLEM STATEMENT

In optimizing the oil recovery of a reservoir, a value of minimum miscible pressure (MMP) should be estimated first. MMP can be determined by experiment, but as the technology developed, this MMP can be determined by simulation. However, there are always factors that will affect every decision. Some factors that affect the value of MMP are the number of pseudocomponent that is used in simulating the reservoir, and also type Equation of State (EOS) that is used to characterize the reservoir.

Different EOS and number of pseudocomponents used in simulating the slim-tube experiment will give different prediction of MMP values. However, there is no 'rules of thumb' that clearly specify the optimum number of pseudocomponents to be used in simulation which may give accurate MMP value estimation. Besides, EOS also gives different results for every different way it is tuning and characterized towards the reservoir model. This shows that these two factors influence the MMP result.

This project basically will study on the relationship of number of pseudocomponent, EOS characterization and MMP values. Literature reviews were done on papers and journals that had carried out studies related to these three elements and some simulations also will be carried out to get better outcome. The expected outcome is the different values of MMP for different number of pseudocomponent used and different type of EOS applied.

1.3 OBJECTIVE & SCOPE OF STUDY

1.3.1 Objective of Study

The objectives of this study are to:

- Determine optimum number of pseudocomponents for miscible process
- Perform and evaluate EOS characterization for slim-tube simulation
- Compare minimum miscibility pressure (MMP) from both pseudocomponents selection and EOS characterization from slim-tube simulation.

1.3.2 Scope of Study

The scope of study involved would be on reservoir field, with specification on miscibility pressure for EOR. This study scope includes gathering information on MMP, EOS model and characteristics and also pseudocomponents properties. There were also some simple calculations in solving EOS and pseudocomponents, as well as simulations to predict the MMP for different EOS and different selection of number of pseudocomponents. However, this project scope does not include EOS tuning characterization effect, since the focus is only on pseudocomponent selection and EOS model characterization. Other than that, some analysis of the result of the study were also done and discussed for better outcomes.

1.4 RELEVANCY & FEASIBILITY OF PROJECT

This topic is mainly related to the reservoir studies, with specialization on the enhanced oil recovery (EOR). EOR is an important element in hydrocarbon production as we have to optimize the well production before it being abandoned. The study of EOS characterization and pseudocomponent in EOR modeling had widely been done by experts and engineers around the world, especially when it involves the gas injection for miscible displacement of the oil.

The main objective of EOS characterization and modeling is to predict the fluid behavior of the reservoir system (Thomas et al., 2004). The displacement process design in EOR may depends on pressure and fluid compositions, which mean an EOS

should be used to simulate the equilibrium mass transfer between phases and PVT behavior of the fluids. EOS can be used to predict behavior for the entire composition path and pressure range of the process, including the miscible pressure. Thus, EOS characterization of measured PVT data is very important for good evaluation and prediction of the reservoir performance.

Since this project only require the student to use the software (ECLIPSE PVTi) to model and do the simulation, thus it is feasible enough to be done within the time frame, provided that there are sufficient data input and variables available.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO ENHANCED OIL RECOVERY AND GAS MISCIBLE DISPLACEMENT

During the early days of the petroleum industry, reservoirs were allowed to produce naturally, without intervention in the reservoir, until it reaches a certain stage of depletion, which is when the production rates had become uneconomic. This natural depletion is known as primary production phase. Next, in the second phase, the recovery was increased by installing methods of artificial drive; either water or gas injection, purposely for pressure maintenance and these are called as secondary recovery methods.

Later, when secondary method has reached its maximum recovery, yet there is still an amount of reserves in the reservoir that is economical to be produced, then it is time to apply the tertiary recovery. The main difference between secondary and tertiary recovery is that tertiary recovery method involves modification of the fluid properties within the reservoir, whereby secondary recovery does not. Tertiary recovery is also known as enhanced oil recovery (EOR).

Abdus Satter and Ganesh Thakur (1994) describe that "EOR can be classified into:

- Thermal methods: Steam simulation, steamflooding, hot water drive and in-situ combustion.
- Chemical methods: Polymer, surfactant, caustic and micellar/polymer.
- Miscible methods: Hydrocarbon (HC) gas, Carbon dioxide (CO_2) and Nitrogen (N_2). Flue gas and partial miscible/immiscible gas also considered." (p. 172)

Figure 2.1 on the next page shows the classification of EOR recovery mechanisms.

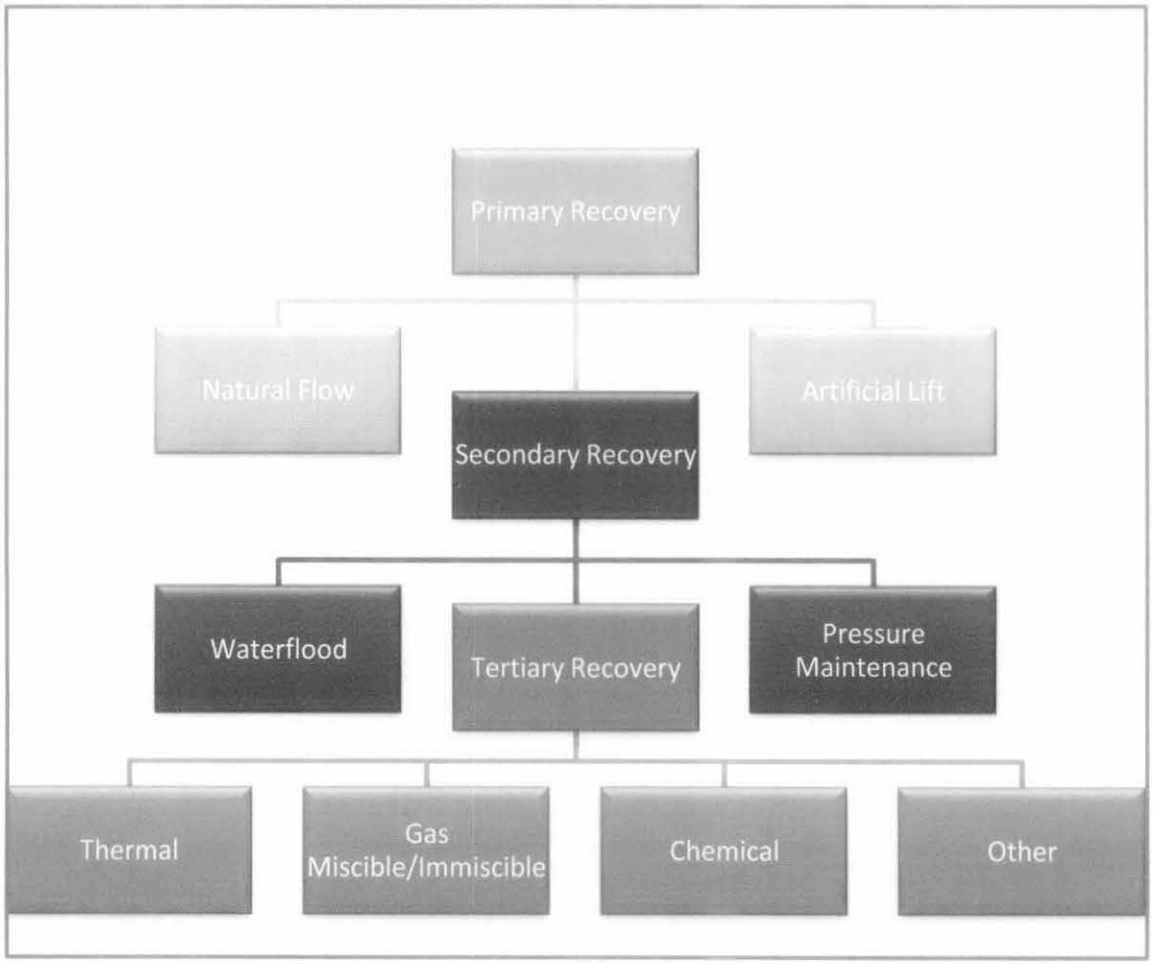

Figure 2.1: EOR Recovery Mechanisms. Source: OGJ (OGJ Special), April 1992.

Oil reservoirs contain both water and hydrocarbon. The distributions of these two elements are being controlled initially by mobility ratio and capillary forces. Oil/water mobility ratio compares oil and water viscosities and relative permeability at a given saturation. Favorable mobility occurs when the viscosities of the oil and water are similar and unfavorable mobility occurs when there are large differences in viscosities, resulting in lower recovery factors for a similar pore volume injected. Oil and water are immiscible which means capillary forces is high and therefore a tension exists at the fluid interface. Therefore, an efficient EOR method should either improve displacement efficiency by eliminate or reduce the capillary forces, or enhance sweep

efficiency by reducing the mobility ratio between injected fluids and in-place fluid, or more efficiently, act on both.

Rapid technology in petroleum industry nowadays has identified many EOR methods in order to achieve efficient EOR. Common fluids that are used to be injected during EOR are such as gases, polymers, foam, surfactant, micro-emulsions, carbon dioxide (CO_2), etc.

2.2 MECHANISMS FOR GAS MISCIBILITY WITH OIL

According to Zein Wijaya (2006):

> Generally, miscibility between two different fluids can be attained through two mechanisms, which is from first-contact miscibility or multiple-contact miscibility. When two different fluids become completely miscible, they form a single-phase fluid, which at this point, one fluid can completely displace the other fluid, leaving no residual saturation. In order to achieve this miscibility, a minimum pressure is required.
>
> Examples of the first one are ethanol and water, and also butane and crude oil. Both mixtures will immediately form one phase without observable interface, regardless the proportions of fluids. While the second one, the injection gas is not miscible with reservoir oil on first contact, but require many contacts in which components of oil and gas transfer back and forth until it mix together. This is called as process condensing/vaporizing mechanism.
>
> The mechanism begins with the gas first condenses into the oil, making it lighter and becomes 'oil bank'. Then, the lighter components of the oil vaporize into the gas rich phase, becoming denser, thus more easily soluble in oil. During this time, mass transfer will always occur between both injection gas and oil until there is no distinguished interface between the injection gas and oil.
>
> (p.28, 29)

2.2.1 First-Contact Miscibility

Zein Wijaya (2005) stated that first-contact miscibility can be defined as a condition when the injected solvent completely mix together with the reservoir oil and produce a single phase fluid (p.29). First-contact miscibility is the lowest pressure at which samples will always be single-phase in all proportions. The injected fluid, which is gas, will get contacted with reservoir fluid, which is oil, and form slug. A practical example of first-contact miscibility is an LPG slug. Theoretically, first-contact miscibility can be achieved with most gases, but it really requires the pressure to be high enough, where in real cases, pressures are generally too low for this type of miscibility to occur. Furthermore, it is needed to inject high-concentration of solvent, which is expensive.

2.2.2 Multi-Contact Miscibility

For reservoirs with initial pressure below first-contact miscibility pressure, there is an alternative processes that can also give miscibility, at multi-contact miscibility pressure instead. Multi-contact miscibility pressure is the lowest pressure at which samples will become single-phase after multiple contacts. There are two types of multi-contact miscibility; condensing gas drive and also vaporizing gas drive. For condensing gas drive, rich gas is injected into the reservoir, while for vaporizing gas drive, lean gas such as methane, CO2 or nitrogen, is used to 'push' the oil out from the reservoir. In this condensing/vaporizing gas drive, forward moving gas (like a vaporizing gas drive) becomes richer in the middle intermediates and heavier fractions. At the same time it loses the light intermediates (like a condensing gas drive). Usually, the forward moving (injection) gas becomes more similar to the reservoir oil, which described miscibility condition. Miscibility is achieved within a transition zone:

- Front of transition zone = Vaporizing Gas Drive (VGD)
- Tail of transition zone = Condensing Gas Drive (CGD)

Figure 2.2 below illustrates the gas injection mechanisms for multi-contact miscibility in real reservoir field:

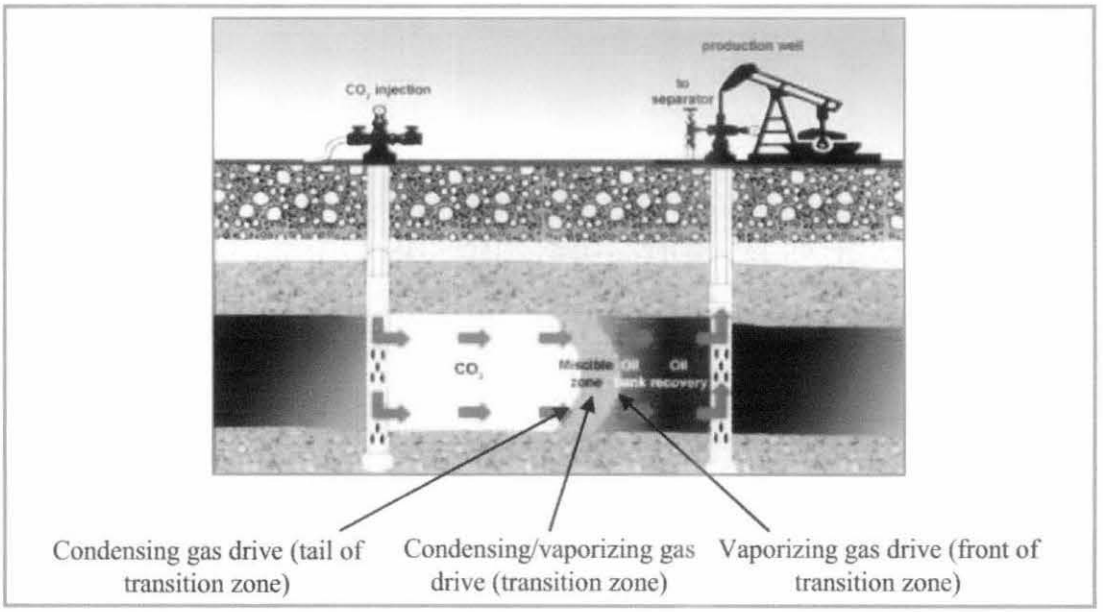

Figure 2.2: Illustration of gas miscibility injection for multi-contact miscibility. Source: http://s4.hubimg.com/u/494443_f496.jpg

From the figure above, we can see that the transition zone is between the CO_2 and the oil bank zone. Here, the mechanism occur would be both vaporizing and condensing drive. At the front of the transition zone, which is near to production well, the miscibility is caused by vaporizing gas drive mechanism. This means that the reservoir oil vaporized into injected gas, due to the difference in molecular weight of both two fluids.

At the tail of the transition zone, which is near to the injection wellbore, this is where the condensing drive occur. The injection of fresh gas will be in contact for the first time with the reservoir oil. When both fluids are contacted, the gas will condensed into the reservoir oil, which also due to the difference of molecular weight of both fluids. After sometimes, some of the gas has condensed into oil, leaving some other part still in the gas phase. This situation is referred as transition zone, where there is condensing gas drive mechanism and also vaporizing gas drive mechanism at the same time.

2.3 MINIMUM MISCIBLE PRESSURE

Miscible flooding by gas injection has nowadays become one of the most important conventional EOR methods. Injection gas-reservoir oil minimum miscibility pressure (MMP) is the most important parameter in designing gas miscible flood (MM Kulkarni, 2003). MMP is required in order to achieve the dynamic miscibility among oil and injection gas. Stalkup Jr. (1983) mentioned that MMP is significant for screening and selecting reservoirs for miscible gas injection projects and is defined as the minimum pressure at which oil and gas exist in one phase. This MMP is typically determined by conventional method, which is through laboratory slim tube experiments. As the conventional approaches, determining MMP is very time-consuming and cost expensive. Other alternatives to estimate the MMP are by calculation, or simulation. It is always preferred to perform more realistic and accurate analytical calculation, or simulation to estimate the MMP.

Egwuenu et al. (2008) says that gas injection into oil reservoirs results in complex interactions of flow with phase behavior that often are not modeled accurately by black-oil simulation. This is especially true for miscible or nearly miscible floods in which significant mass transfer occurs between the hydrocarbon phases (Thomas et al., 2004). Such floods are modeled best by compositional simulation. However, there is a significant disadvantage of compositional simulation in which it is more computationally intensive than black-oil simulation (Egwuenu et al., 2008). Y. Li (2005) mentioned that the primary reason for the increased computational time is the result of solving repeated flash calculations with cubic EOS. Therefore, the need of fewer pseudocomponents could reduce the flash computation time, but fewer components would results in poor fluid characterizations and less accurate outcome.

The figure 2.3 (a & b) on the next page shows the MMP estimations from the slim-tube experiment, by plotting the graph of recovery versus pressure.

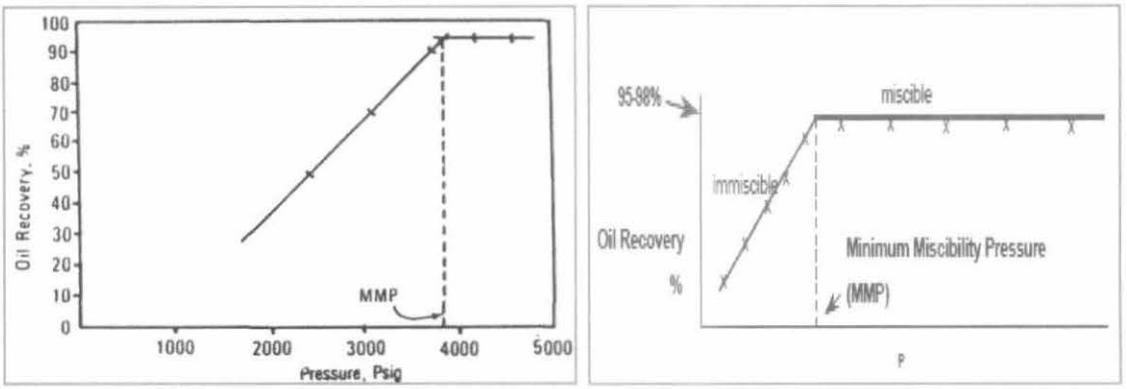

Figure 2.3 (a & b): Example of MMP estimation from the slim tube experiment (graph of oil recovery versus pressure). MMP interpreted at the slope changes in recovery. Source: http://lout-de-chevalier.blogspot.com and ECLIPSE 300 Manual (Introduction to PVT Analysis and Compositional Simulation).

From the papers, it is widely recognized that major factors affecting CO_2-oil MMP are oil composition and reservoir temperature. It is indicated that the presence of volatile components such as methane helped to increase MMP, while the presence of intermediates C2 to C6 helped to decrease MMP (MK Emera, 2005). In addition to that, it is also proved that heavier gravity oil (as C5+ increases), MMP also increases.

2.3.1 MMP Estimation through Experiment

First method of MMP value estimation is from the experiments. MMP values can be obtained either from slim-tube experiment or rising bubble experiment. The most common experiment however, is the slim-tube experiment. This experiment has been accepted as a standard method to measure MMP in the petroleum industry (Motaleby Nedjad et al., 2007). Figure 2.4 on the next page shows the diagram of slim-tube experiment apparatus.

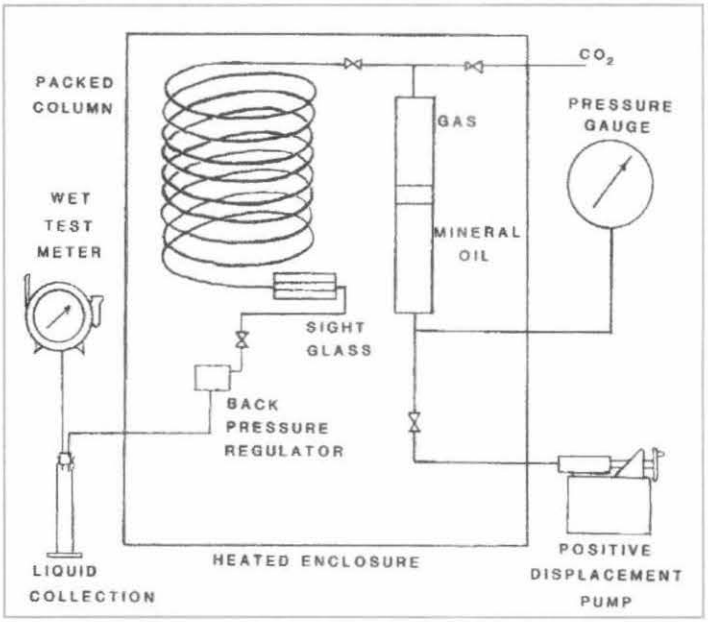

Figure 2.4: Diagram of Slim-Tube Apparatus. Source: http://www.kgs.ku.edu/CO2/Presentation/Jyun-Syung/sld007.htm

Motaleby Nedjad et al. (2007) also described that initially, the tube is filled with oil at reservoir temperature above the bubble point pressure. Then, injecting gas displaced the oil in the tube at a constant pressure, which is controlled by a back pressure regulator. After that, the slim tube effluent is flashed at the atmospheric condition and the oil recovery is measured. The plot of Oil Recovery versus Pressure is plotted then, and the MMP is estimated at which the breakover point criterion (Svetlana N. Rudyk et al., 2007). This is as shown by Figure 2.2 (a & b).

2.3.2 Analytical method of MMP Estimation

Motaleby Nedjad et al. (2007) explained the analytical theory that the behavior of the displacement is completely controlled by a sequence of key tie lines; initial tie-line (the one that extend through the initial oil composition), injection tie-line (extend through the injection gas composition) and nc-3 tie lines, also known as crossover tie lines. This is shown by 1-Dimension, dispersion free displacement of oil by injection gas with nc components. This theory demonstrated that multi-contact miscibility will

be developed when dispersion-free displacement becomes piston-like, which is when any one of the key tie lines becomes a critical tie line. Therefore, MMP is calculated as the lowest pressure at which any one of the key tie lines becomes a critical tie line, i.e. its length approaches to zero (H. Yuan et al., 2005). This can be illustrates by Figure 2.5 below.

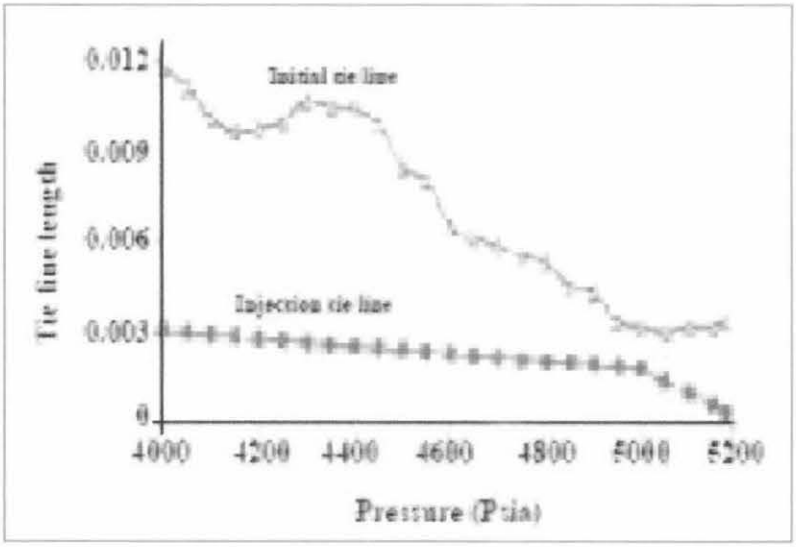

Figure 2.5: An example of key-tie-line length versus pressure graph. Source: Motaleby Nedjad et al., 2007).

2.3.3 MMP Estimation by Simulation

The used of experiment methods and analytical techniques to study miscibility of fluids are usually time consuming and consequently costly. Therefore, a detail planning of which experimental conditions to apply is very important. An experiment of injection study of multiple contact miscibility experiment may be performed or a slim tube experiment may be simulated in order to help reducing on the pressures needed to get the part of the recovery curve of interest. Figure 2.6 on the next page shows the windows of experiment entry of multiple contact miscibility experiment of injection study experiment using software ECLIPSE PVTi.

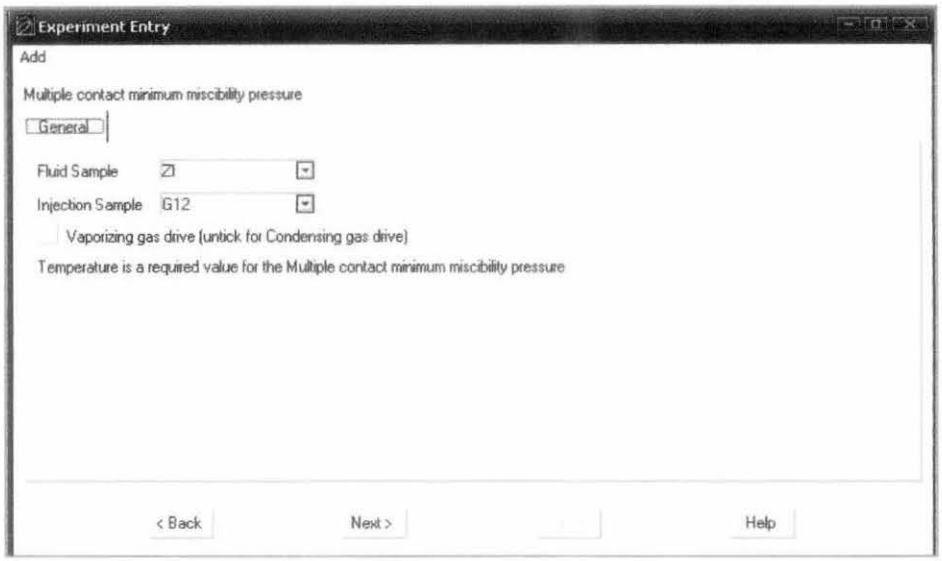

Figure 2.6: Experiment entry of ECLIPSE PVTi.

Besides that, for real laboratory experiment, the error and uncertainties in the measurements make it harder to determine the actual MMP with great accuracy. In a similar slim-tube experiment simulation, the PVT laboratory can give measurement of the minimum enrichment needed to achieve multi-contact miscibility at a given pressure. In other words, this experiment performs a minimum miscibility pressure evaluation. The necessary inputs are the fluid sample, the injected fluid sample, temperature and the type of injection drive (either condensing or vaporizing drive).

2.4 EQUATION OF STATE (EOS) MODEL

An EOS is an analytical expression relating the pressures, p, to the temperature, T, and the volume, V. An appropriate description of this PVT relationship for real hydrocarbon fluids is essential in determining the volumetric and phase behavior of reservoir fluids, and EOS can accurately describe this. The main advantage of using EOS is that the same equation can be used to model the behavior of all phases, thus assure the consistency when performing phase equilibria equation.

The best known and the simplest example of an equation of state is the ideal gas equation:

$$p = \frac{RT}{V}$$

This PVT relationship is used to describe the volumetric behavior only for real hydrocarbon gases at pressures close to the atmospheric pressure for which it was experimentally derived. Due to limitations of the applicability of the above equation, thus efforts to improve the capability of the equations had been done so that it is suitable for describing the behavior of real fluids at extended ranges of pressures and temperatures. Some of the developments are Van der Waals, Redlich-Kwong, Soave-Redlich-Kwong, and Peng-Robinson. For this project, the EOS models that were applied are the Soave-Redlich-Kwong (SRK), Peng-Robinson (PR), and also Schmidt-Wenzel EOS.

Peng-Robinson EOS: $$\left[p + \frac{a_T}{V_M(V_M + b) + b(V_M - b)}\right](V_M - b) = RT$$

where:

$$A_C = 0.45724 \frac{R^2 T_C^2}{P_C}$$

$$\alpha^{1/2} = 1 + m(1 - T_r^{1/2})$$

$$b = 0.07780 \frac{RT_c}{P_c}$$

$$m = 0.37464 + 1.54226\omega - 0.26992\omega^2$$

, $$\omega = -(\log p_{vr} + 1)$$

Soave-Redlich-Kwong EOS: $$[p + \frac{a_T}{V_M(V_M + b)}](V_M - b) = RT$$

where: $$a_c = 0.42747\frac{R^2 T_c^2}{p_c}$$ $$b = 0.08664\frac{RT_c}{p_c}$$, $$m = 0.480 + 1.574\omega - 0.176\omega^2$$, $$\omega = -(\log p_{vr} + 1)$$

2.5 EOS CHARACTERIZATION & PSEUDOCOMPONENT SELECTION

According to Egwuenu et al. (2008):

> EOS is used to predict the compositions and volumetric behavior that result when oil mix with gas in the reservoir. These EOS fluid characterizations must be tuned to match the PVT behavior of the original reservoir fluid. The process of tuning an EOS involves: First; the selection of the pseudocomponents, second; the determination of EOS properties by regression to the properties for the pseudocomponents, and third; the adjustment of pseudocomponent EOS properties by regression to the PVT data. The fluid characterizations that result from the lumping and tuning process are dependent on the method used and the experimental PVT data available.
>
> The tuning process involves lumping the original fluid analysis to as few as 12 to 15 components and pseudocomponents. This EOS model is tuned to match the available PVT data, and it can be lumped into fewer pseudocomponents as required.

In order to get better result, the experiment results were regressed few times by tuning the EOS, which includes changing the properties of the plus component. For example, critical temperature (T_c), critical pressure (P_c), ω_a, and ω_b. This is because; most of the experiment observations are sensitive to these properties, especially the saturation pressure.

The main basis for lumping or grouping is to assemble components with similar molecular weights since they might have similar properties. For instance, group C7 together with C8. Clear candidates are to group iC4 with nC4 becomes C4, and to group iC5 with nC5 to become C5. However, there is an exception to this rule, which is N_2, is usually added to C1 and CO_2 is usually added to C2. For the case of non-HC component, the grouping process should not depend on their molecular weights. This is because of the different in properties of non-HC and HC component. Therefore, we should not group N_2 (MW=28) with C1 (MW=16), but with C2 (MW=20) instead. Similarly, CO_2 (MW=44) are not with C3 (MW=44), but with C2 alternatively.

There are several theories or methods for lumping plus components into pseudocomponents and determining their properties. The simplest methods are by assigning pseudocomponents on the basis of component mole fractions (Cotterman & Prausnitz 1985), mass fractions (Pedersen et al. 1985), ranges in molecular weights (Whitson 1983) and K-values (Li et al. 1985; Newley and Merill 1991) pore-complex methods including the statistical approach of Mehra et al. (1982).

Curtis H. Whitson (1999) said that usually, three to five C7+ fractions (or two to three C10+ fractions) should be used. The Whitson et al. splitting/characterization procedure is recommended for the PengRobinson EOS, while the Pedersen et al. method is recommended for the Soave-RedlichKwong EOS, where each plus fraction has equal mass fraction.

In PVTi simulation software however, the techniques available for splitting the plus-fractions into subfractions (pseudocomponents) are Constant Mole Fractions (CMF), Whitson, Multi-Feed and PNA Distribution. For this project, the constant mole fractions method was chosen to be used to split the fluid component into pseudocomponents.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

The methodology of this study involved literature studies and information gathering regarding the project topic, familiarization to the software used (ECLIPSE PVTi), simulation and modeling using the software, and also analysis based on the design or output from the simulation. Firstly, researches and studies that related to pseudocomponent selection, EOS characterization and MMP estimation were done. Literature sources such as experimental studies reports, journals and papers helped a lot in giving clearer understanding about the concepts.

Next is the familiarization to ECLIPSE PVTi, the software that is used to model and simulate the EOS in predicting the MMP. After been familiarized with ECLIPSE PVTi, then some simulations were carried out and sensitivity analysis of the results were done to see the effect of number of pseudocomponent selection and EOS characterization used in predicting the miscibility pressure. Figure 3.1 and 3.2 below show the research and overall project methodology.

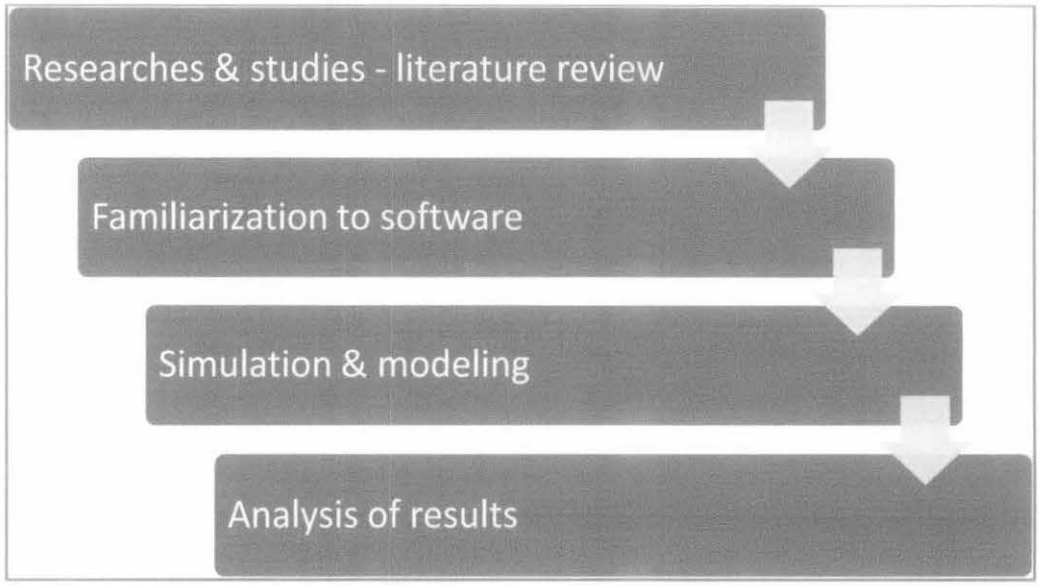

Figure 3.1: Research methodology.

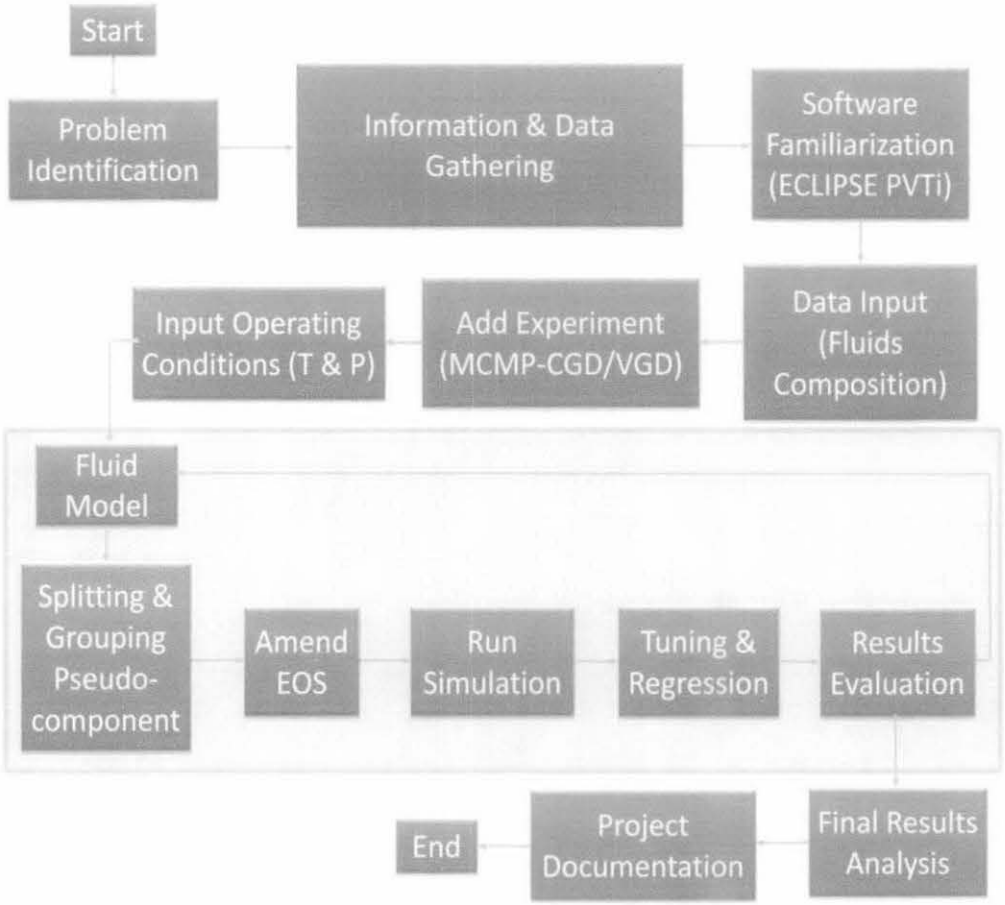

Figure 3.2: Project methodology flow chart.

More detail procedure on the simulation using ECLIPSE PVTi is presented in the Appendix section.

For data gathering, the author used the data from a thesis report[27] of Zein Wijaya. (2006). Two set of reservoir fluid samples is taken from the report and 1 data set of injection gas in taken. The report contains result from the lab experiment which will be used to compare with this project results. The results from the simulation of this project is compared with the MMP results of slim-tube experiment in the report.

3.2 PROJECT ACTIVITIES

The project activities of this study are divided into two major classes of tasks which are main task and sub-task. The main tasks are consisted of:

- Planning
- Information gathering and literature review
- Simulation and modeling
- Sensitivity analysis of the results obtained.

While the sub-tasks, on the other hand, are consisted of:

- Progress reporting
- Completing final reporting, or dissertation
- Preparing technical report
- Conduct oral presentation and etc.

3.3 KEY MILESTONES

Figure 3.3 below shows the key milestone of the project:

Figure 3.3: Project key milestones.

3.4 GANTT CHART

Below is Table 3.1, the project Gantt chart, which visualizes the plan for the project flow from the beginning till the end of project period.

NO	ACTIVITY	DATE	WEEK											
			3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work													
2	Part 1: EOS Characterization													
3	Introduction & Literature Review													
4	Part 2: Pseudocomponent Selection													
5	Methodology													
6	Analysis on Results													
7	Results & Discussion, Conclusion & Recommendation													
8	Progress Report Submission	16/3/2011												
9	Pre-EDX (Poster & Seminar)	4/4/2011												
10	Final Report Submission	4/4/2011												
11	Technical Paper Submission	TBA												
12	EDX	11/4/2011												
13	Final Oral Presentation	20/4/2011												

Table 3.1: Project Gantt chart.

3.5 TOOLS

Basically, engineering simulation software called ECLIPSE PVTi was used in this project. PVTi is actually a compositional PVT EOS-based program which has ability to characterize a set of fluid samples that are going to be used in ECLIPSE simulators. Using PVTi, experiments that have been carried out in the lab can be simulated, and the results from the simulation would be theoretical predictions.

CHAPTER 4

RESULTS & DISCUSSION

During the project work, there are several constraints that were found during this first phase of project. The main constraint that can be listed out is problem in doing simulation/modeling. Since the author is not familiar with the software, then it took some time for the author to be familiar with the basic functions of the software.

However, the author managed to reduce all the constraints after some times, by having readings on literature papers, discussions with project supervisor and learning the functions of the software.

For this project, there are two cases of injection study experiment that were simulated; multi-contact miscibility using rich gas (condensing gas drive/CGD) and also multi-contact miscibility using lean gas CO_2 (vaporizing gas drive/VGD) simulation. The results are as follows:

Case 1: Reservoir fluid with rich injection gas: condensing gas drive.

Temperature = 376.45 K	
P_{sat} = 270.00 bar	MMP observed = 327.00 bar

Table 4.1: The given information of Fluid 1.

No	No. of pseudocomponents	EOS	Calculated MCMP (PVTi), bar	% error
1	4	PR	312.2799	4.50
2	4	SRK	339.4581	3.81
3	4	SW	293.5411	10.23
4	5	PR	305.9389	6.44
5	5	SRK	325.0802	0.59
6	5	SW	290.2692	11.23
7	6	PR	279.9647	14.38
8	6	SRK	320.9066	1.86

9	6	SW	279.9647	14.38
10	7	PR	292.7213	10.48
11	7	SRK	333.7298	2.06
12	7	SW	279.9446	14.39

Table 4.2: Results of Calculated MCMP for different EOS and number of pseudocomponent for Case 1.

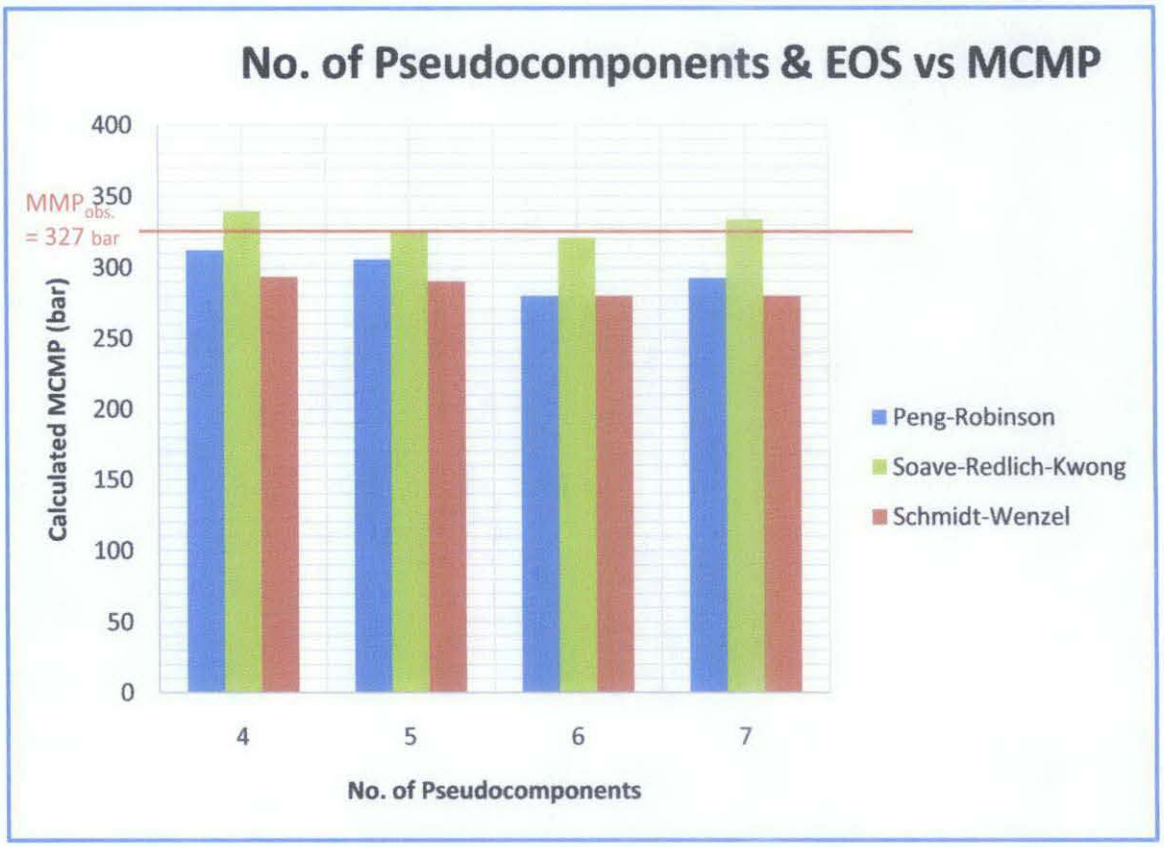

Figure 4.1: Bar chart of Calculated MCMP versus No. of Pseudocomponent and EOS for Case 1.

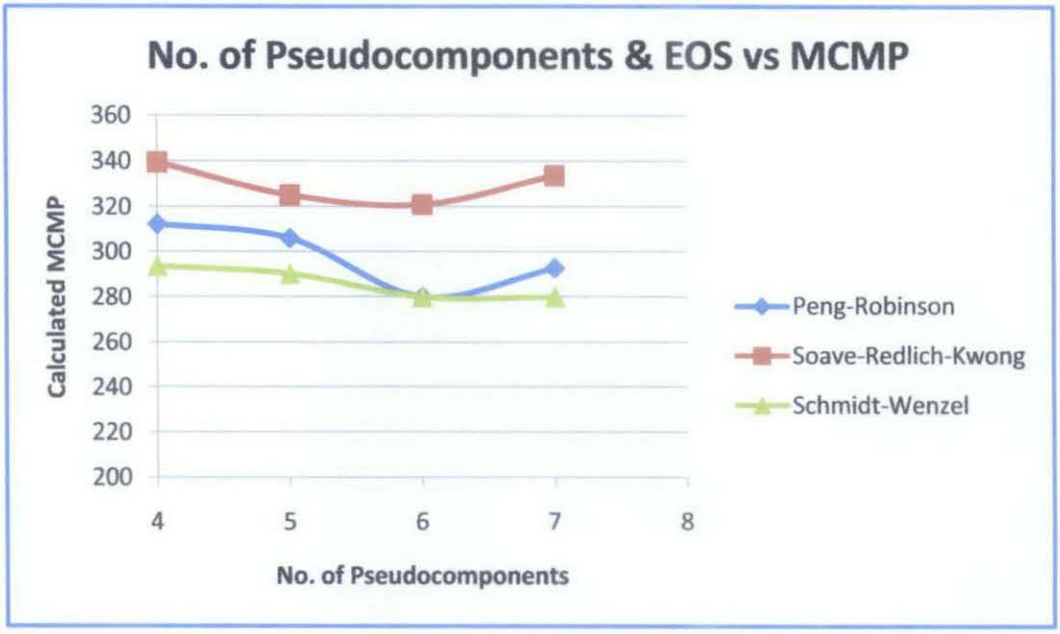

Figure 4.2: Graph of Calculated MCMP versus No. of Pseudocomponent and EOS for Case 1.

As can be seen from both graphs above, the most accurate MCMP calculated was given by SRK EOS with 5 pseudocomponents. Besides that, it is also shown that this EOS provides the least error (0.59%) among other EOS (refer Figure 4.3 below). We can also observe that the results are not consistent as the points are scattered away from each other.

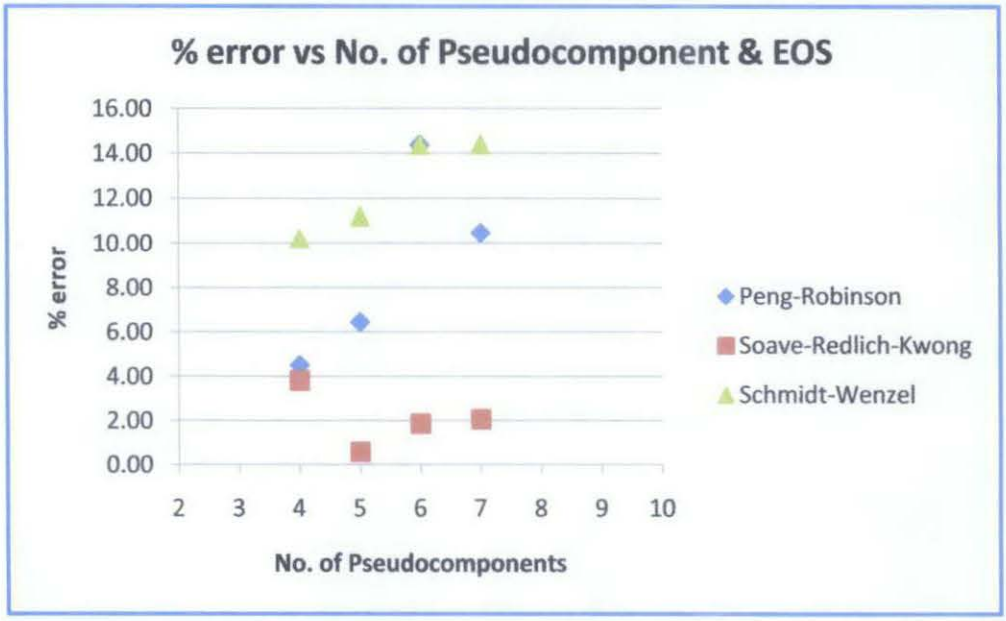

Figure 4.3: Graph of % error versus no. of pseudocomponent & EOS for Case 1.

Case 2: Reservoir fluid with lean CO_2 injection gas: vaporizing gas drive.

Temperature = 377.55 K	
P_{sat} = 171.00 bar	MMP observed = 271.00 bar

Table 4.3: The given information of Fluid 2.

No.	No. of pseudocomponents	EOS	Calculated MCMP (PVTi), bar	% error
1	4	PR	263.6850	2.70
2	4	SRK	272.8359	0.68
3	4	SW	263.3944	2.81
4	5	PR	253.8550	6.33
5	5	SRK	265.4422	2.05
6	5	SW	253.9175	6.30
7	6	PR	253.2040	6.57
8	6	SRK	260.3897	3.92
9	6	SW	249.9948	7.75
10	7	PR	246.9454	8.88
11	7	SRK	256.5866	5.32
12	7	SW	250.1958	7.68

Table 4.4: Results of calculated MCMP for different EOS and number of pseudocomponents for Case 2.

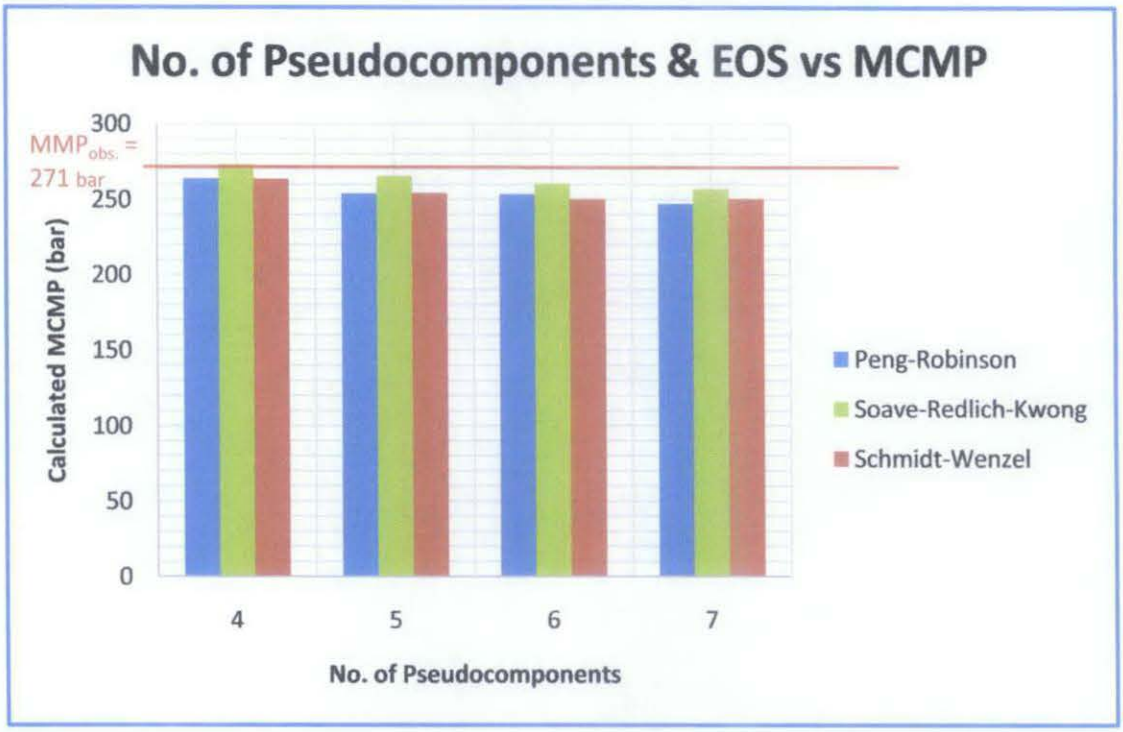

Figure 4.4: Bar Chart of Calculated MCMP versus No. of Pseudocomponent and EOS for Case 2.

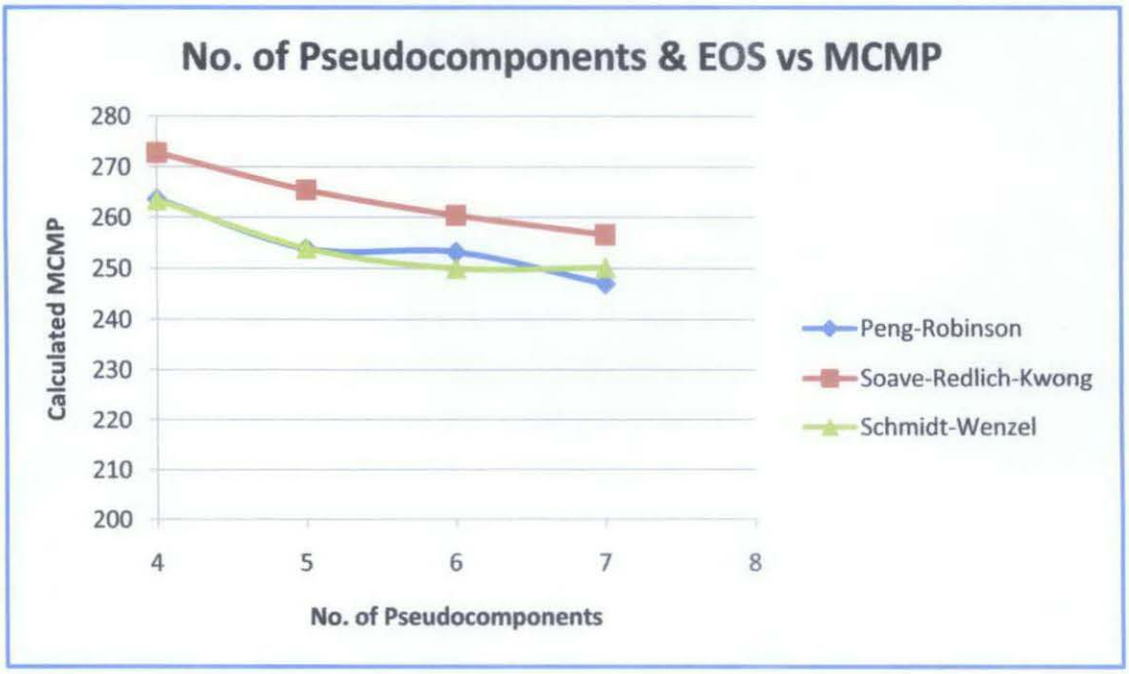

Figure 4.5: Graph of Calculated MCMP versus No. of Pseudocomponent and EOS for Case 2.

As can be seen from the graphs on the previous page, the most accurate MCMP calculated was given by SRK EOS with 4 pseudocomponents. Besides that, it is also shown that this EOS provides the least error (0.68%) among other EOS (shown by Figure 4.6 below). From the graph, it is also observed that that the results are not really consistent as the points are scattered away from each other, which is similar to Case 1 results.

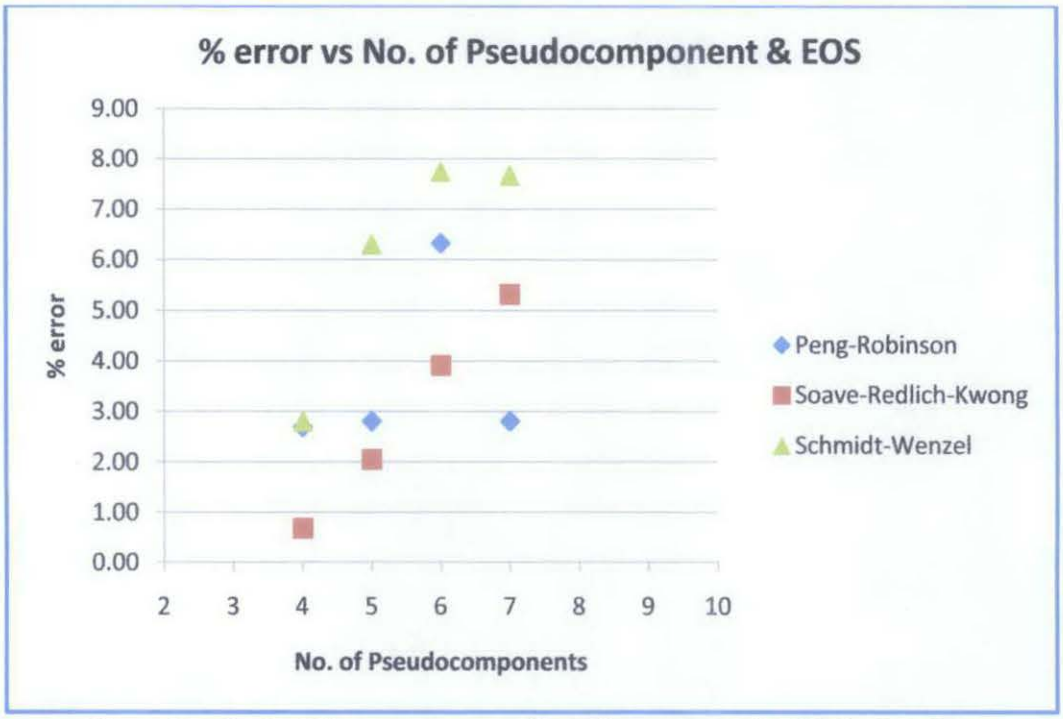

Figure 4.6: Graph of % error versus no. of pseudocomponent & EOS for Case 2.

From both cases, we can say that SRK EOS usually predicting greater value of MCMP than other EOS. From both cases, MCMP of Case 1 is higher than Case 2. This means that MCMP of condensing (rich) gas drive is much higher than vaporizing (lean) gas drive. This is due to higher pressure is required by the gas to condense into oil or become miscible with the reservoir fluid, instead of oil vaporizes and miscible with gas.

Number of pseudocomponents is not directly proportional to the value of MCMP estimated (i.e. greater no. of pseudocomponents not necessarily gives greater value of MCMP estimation). It varies for every pseudocomponents number, and no unique pattern is observed for this factor.

CONCLUSION

A detail study and understanding were required in this project so that the objective can be achieved successfully. The simulations on varying number of pseudocomponent and EOS characterization were done so that the influence of these two elements in determining the MMP value can be clearly seen.

From the simulation, the optimum number of pseudocomponents for miscible gas injection simulation is 4 for lean gas injection and 5 pseudocomponents for rich gas injection. It is simulated that EOS Soave-Redlich-Kwong (SRK) gives most accurate value among other EOS for both cases, i.e. with % error of 0.68 for lean gas injection and 0.59 for rich gas injection, as compared to the reported MMP values observed from slim-tube experiment.

As a conclusion, the results from the simulation shows that the optimum number of pseudocomponents used to estimate MMP values are depends on type of the injection gas used. It is also depends on how the experiment (slim-tube) being simulated, i.e. the way the plus component is splitted and re-grouped, and also how the model is regressed and tuned.

RECOMMENDATIONS

This project could be improved if more additional fluid samples are added as different miscibility cases. For example, this project now has only 2 cases of fluid samples or miscibility conditions. Case 1 is common reservoir fluid with injection of rich injection gas (condensing gas drive), whereas Case 2 is common reservoir fluid with injection of lean CO_2 gas (vaporizing gas drive). If more samples and cases are added, then the consistency of the results obtained from the simulation can be ensured.

Besides that, it is well recommended that this project would be continued with simulation and modeling using software ECLIPSE 300, so that better results and outcomes could be obtained and analyzed, and therefore more clear comparison of the results can be done.

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APPENDIX A

Table 12
Molar compositions related to reservoir fluid F_{12} (144 experimental values)

Compound	Reservoir fluid (F_{12})	First stage conditions: T_{stock}/°C = 15.0; P_{stock}/bar = 1.01325; tank oil density (kg/m³) = 835.7		Properties of the cuts from C_6 to C_{20}^+	
		Residual gas	Stock tank oil	Molar weight (g/mol)	Density at 15 °C (kg/m³)
(1) Hydrogen sulfide	1.490	4.000	0.000		
(2) Nitrogen	0.320	0.080	0.000		
(3) Carbon dioxide	2.800	4.100	0.000		
(4) Methane	45.290	42.180	0.000		
(5) Ethane	9.110	18.890	0.540		
(6) Propane	5.500	15.050	1.800		
Cut C_4					
(7) *i*-Butane	1.060	2.640	0.840		
(8) *n*-Butane	3.070	7.750	2.690		
Cut C_5					
(9) *i*-Pentanes	1.240	1.700	2.280		
(10) *n*-Pentane	1.820	2.020	3.940		
Cut C_6					
(11) *i*-Hexanes	1.210	0.340	3.460	86.0	678.8
(12) *n*-Hexane	1.170	0.330	3.360		
Cut C_7					
(13) *i*-Heptanes	0.350	0.070	1.060	92.0	727.1
(14) Benzene	0.180	0.040	0.530		
(15) Cyclanes C7	1.690	0.340	5.070		
(16) *n*-Heptane	0.620	0.120	1.870		
Cut C_8					
(17) *i*-Octanes	0.470	0.050	1.450	106.0	736.7
(18) Toluene	0.490	0.050	1.500		
(19) Cyclanes C8	1.340	0.150	4.100		
(20) *n*-Octane	0.530	0.060	1.620		
Cut C_9					
(21) *i*-Nonanes	0.570	0.010	1.800	120.0	764.5
(22) Aromatics C9	0.850	0.010	2.670		
(23) Cyclanes C9	0.590	0.010	1.850		
(24) *n*-Nonane	0.480	0.010	1.500		
Cut C_{10}					
(25) *i*-Decanes	1.300	0.000	4.090	137.0	777.8
(26) Aromatics C10	0.450	0.000	1.430		
(27) *n*-Decane	0.400	0.000	1.250		
(28) Undecanes (*cut* C_{11})	1.740	0.000	5.500	148.0	791.3
(29) Dodecanes (*cut* C_{12})	1.420	0.000	4.490	164.0	798.2
(30) Tridecanes (*cut* C_{13})	1.310	0.000	4.150	174.0	810.3
(31) Tetradecanes (*cut* C_{14})	1.150	0.000	3.650	188.0	814.0
(32) Pentadecanes (*cut* C_{15})	1.000	0.000	3.150	203.0	835.5
(33) Hexadecanes (*cut* C_{16})	0.880	0.000	2.790	218.0	847.7
(34) Heptadecanes (*cut* C_{17})	0.760	0.000	2.410	232.0	850.4
(35) Octadecanes (*cut* C_{18})	0.690	0.000	2.180	249.0	862.6
(36) Nonadecanes (*cut* C_{19})	0.620	0.000	1.960	261.0	874.5
(37) Eicosanes plus (C_{20}^+)	6.040	0.000	19.030	460.0	939.0

APPENDIX B

Table 13
Molar compositions related to reservoir fluid F_{13} (220 experimental values)

Compound	Reservoir fluid (F_{13})	First stage conditions: T_{sep}/°C = 48.9; P_{sep}/bar = 6.6		Second stage conditions: T_{stock}/°C = 15.0; P_{stock}/bar = 1.01325; tank oil density (kg/m³) = 846.6		Properties of the cuts from C_6 to C_{20+}	
		Separator gas	Separator liquid	Residual gas	Stock tank oil	Molar weight (g/mol)	Density at 15 °C (kg/m³)
(1) Hydrogen sulfide	0.000	0.000	0.000	0.000	0.000		
(2) Nitrogen	1.252	2.422	0.018	0.619	0.000		
(3) Carbon dioxide	0.897	1.700	0.053	1.731	0.000		
(4) Methane	37.543	71.770	1.427	48.602	0.000		
(5) Ethane	5.476	9.935	0.772	16.704	0.290		
(6) Propane	4.196	6.552	1.709	14.589	1.320		
Cut C_4							
(7) *i*-Butane	1.104	1.369	0.824	3.224	0.751		
(8) *n*-Butane	2.902	3.059	2.736	7.099	2.604		
Cut C_5							
(9) *i*-Pentanes	1.360	0.924	1.820	1.973	1.815		
(10) *n*-Pentane	1.875	1.033	2.764	2.116	2.783		
Cut C_6							
(11) *i*-Hexanes	1.282	0.347	2.269	0.694	2.317	86.0	682.2
(12) *n*-Hexane	1.452	0.393	2.570	0.786	2.624		
Cut C_7							
(13) *i*-Heptanes	0.557	0.060	1.081	0.273	1.105	93.0	712.1
(14) Benzene	0.313	0.034	0.608	0.154	0.622		
(15) Cyclanes C7	1.621	0.176	3.145	0.794	3.216		
(16) *n*-Heptane	1.249	0.136	2.423	0.612	2.478		
Cut C_8							
(17) *i*-Octanes	0.835	0.021	1.694	0.007	1.745	109.3	730.8
(18) Toluene	0.201	0.005	0.408	0.002	0.420		
(19) Cyclanes C8	1.533	0.039	3.109	0.013	3.203		
(20) *n*-Octane	0.986	0.025	2.000	0.008	2.061		
Cut C_9							
(21) *i*-Nonanes	0.895	0.000	1.839	0.000	1.895	121.5	752.5
(22) Aromatics C9	0.590	0.000	1.213	0.000	1.249		
(23) Cyclanes C9	0.772	0.000	1.587	0.000	1.635		
(24) *n*-Nonane	0.809	0.000	1.662	0.000	1.712		
Cut C_{10}							
(25) *i*-Decanes	1.348	0.000	2.771	0.000	2.854	138.6	764.5
(26) Aromatics C10	0.333	0.000	0.684	0.000	0.705		
(27) *n*-Decane	0.500	0.000	1.028	0.000	1.059		
(28) Undecanes (*cut* C_{11})	2.447	0.000	5.028	0.000	5.180	144.4	773.5
(29) Dodecanes (*cut* C_{12})	2.092	0.000	4.299	0.000	4.429	157.7	784.2
(30) Tridecanes (*cut* C_{13})	1.789	0.000	3.677	0.000	3.788	172.1	793.7
(31) Tetradecanes (*cut* C_{14})	1.789	0.000	3.676	0.000	3.787	188.3	806.1
(32) Pentadecanes (*cut* C_{15})	1.885	0.000	3.875	0.000	3.992	205.6	814.2
(33) Hexadecanes (*cut* C_{16})	1.568	0.000	3.222	0.000	3.319	228.0	817.0
(34) Heptadecanes (*cut* C_{17})	1.417	0.000	2.913	0.000	3.001	248.3	823.2
(35) Octadecanes (*cut* C_{18})	0.865	0.000	1.777	0.000	1.831	263.9	829.6
(36) Nonadecanes (*cut* C_{19})	1.098	0.000	2.257	0.000	2.325	272.9	833.8
(37) Eicosanes plus (C_{20+})	3.169	0.000	7.064	0.000	27.885	678.0	899.9

APPENDIX C

Table 14
Molar compositions of the 17 injected gases (183 experimental values)

Compound	G_1	G_2	G_3	G_4	G_{5a}	G_{5b}	G_{5c}	G_{5d}	G_{6a}	G_{6b}	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}
Hydrogen sulfide	–	–	–	–		1.000	1.000	1.070	0.250		–	–	2.350	2.720	–	3.830	–
Nitrogen	0.480	0.480	0.490	0.430		1.150	0.970	1.010	0.420	0.450	–		0.270	0.220	0.470	0.200	–
Carbon dioxide	4.960	4.960	1.820	1.650	–	4.380	3.930	4.240	2.850	2.190	4.350	4.350	4.350	4.430	2.250	7.570	100.00
Methane	58.050	58.050	81.390	83.730	88.000	55.760	55.830	56.470	75.550	76.650	81.140	81.140	73.090	66.100	85.340	64.900	–
Ethane	17.090	17.090	9.150	9.160	7.000	15.030	15.350	15.150	14.340	12.020	10.310	10.310	6.000	6.410	7.620	15.030	–
Propane	11.970	11.970	4.670	4.540	3.000	10.870	11.120	10.760	5.520	5.260	3.320	3.320	3.480	12.040	2.980	5.760	–
Isobutane	1.230	1.230	0.500	0.480	0.500	2.000	2.040	1.920	0.370	0.740	–	–	0.810	0.500	0.320	0.630	–
n-Butane	3.730	3.730	1.240	1.210	0.500	4.370	4.400	4.230	0.590	1.490	0.880	0.880	1.760	6.930	0.690	1.290	–
Isopentane	0.750	0.750	0.200	0.190	0.500	1.500	1.560	1.440	0.050	0.330	–	–	0.730	0.240	0.120	0.250	–
n-Pentane	0.910	0.910	0.260	0.260	0.500	1.620	1.560	1.530	0.050	0.410	–	–	0.920	0.230	0.150	0.280	–
2-Methyl pentane	–	–	–	–		–	–	–	–	–	–	–	–	–	0.060	–	–
n-Hexane	0.530	0.530	0.090	0.130	–	1.320	1.200	1.140	0.010	0.260	–	–	1.150	0.120	–	0.150	–
n-Heptane	0.190	0.190	0.060	0.120	–	0.760	0.840	0.750	–	0.120	–	–	1.100	0.030	–	0.100	–
n-Octane	0.080	0.080	0.130	0.130		0.150	0.220	0.290	–	0.080	–	–	0.920	0.030	–	0.030	–
n-Nonane	0.030	0.030	–	0.010		–	–	–	–	–	–	–	0.730	–	–	–	–
n-Decane	–	–	–		–	–	–	–	–	–	–	–	0.470	–	–	–	–
C_{11}^+	–	–	–	–	–	–	–	–	–	–	–	–	1.870	–	–	–	

APPENDIX D

Table 26
Experimental data in relation with reservoir fluid F_{12} (476 data points)

Isothermal constant mass expansion	T/K = 376.45; P_{sat}/bar = 270.0	P/bar	V_{rel}	ρ_{global} (kg/m^3)
		351.8	0.9763	659.631
		326.3	0.9828	655.308
		302.2	0.9897	650.618
		277.4	0.9975	645.578
		270.0	1.0000	643.915
		264.2	1.0061	640.205
		251.6	1.0210	630.915
		235.3	1.0435	617.284
		217.9	1.0739	599.880
Isothermal constant mass expansion	T/K = 299.85; P_{sat}/bar = 212.4	P/bar	V_{rel}	ρ_{global} (kg/m^3)
		351.4	0.9771	722.543
		301.5	0.9844	717.360
		262.0	0.9909	712.758
		231.0	0.9965	708.717
		212.4	1.0000	706.215
		204.1	1.0069	703.262
		192.2	1.0189	693.001
		178.3	1.0371	680.735
		164.2	1.0618	664.894
Isothermal constant mass expansion	T/K = 360.95; P_{sat}/bar = 256.4	P/bar	V_{rel}	ρ_{global} (kg/m^3)
		351.4	0.9762	671.592
		321.3	0.9829	666.667
		300.2	0.9879	663.570
		261.0	0.9887	656.168

Isothermal constant mass expansion		256.4	1.0000	655.308		
		247.2	1.0096	649.351		
		237.6	1.0211	641.849		
		225.4	1.0380	631.313		
		211.7	1.0613	617.665		
Isothermal constant mass expansion	T/K = 394.25; P_{sat}/bar = 275.0	P/bar	V_{rel}	ρ_{global} (kg/m^3)		
		400.5	0.9658	647.249		
		351.4	0.9775	639.386		
		311.6	0.9883	632.511		
		281.3	0.9980	626.174		
		275.0	1.0000	625.000		
		270.0	1.0053	621.891		
		262.9	1.0135	616.523		
		253.7	1.0250	609.756		
		242.8	1.0407	600.601		
Isothermal differential vaporization	T/K = 376.45	P/bar	V_{rel}	ρ_{liq} (kg/m^3)	GOR_{LG}	Z_{LG}
		351.8	0.9763	659.7	–	–
		326.3	0.9829	655.4	–	–
		302.2	0.9895	650.8	–	–
		277.4	0.9972	645.7	–	–
		270.0	1.0000	644.1	0.0	–
		245.8	0.9492	651.9	33.4	0.880
		201.0	0.8847	672.0	74.2	0.857
		133.8	0.8035	702.7	129.2	0.854
		67.4	0.7340	734.1	177.5	0.889
		33.6	0.6959	753.0	202.4	0.920
		1.0	0.5916	796.8	244.6	0.998
Isothermal swelling test	T/K = 376.45; gas: C_{12}	$100*X_{gas}$	P_{sat}/bar	ρ_{sat} (kg/m^3)	V_{swell}	
		0.00	270.0	644.0	1.0000	
		30.00	348.0	592.8	1.2280	
		40.00	382.8	574.0	1.3500	
		50.00	424.0	552.1	1.5200	
Constant mass expansions during the swelling test	X_{gas} = 0.30	P/bar	V_{rel}	ρ_{global} (kg/m^3)		
		453.8	0.9662	613.497		
		423.5	0.9740	608.643		
		401.8	0.9806	604.595		
		376.4	0.9892	599.161		
		359.4	0.9956	595.238		
		348.4	1.0000	592.768		
		345.0	1.0023	591.366		
		339.8	1.0059	589.275		
		331.4	1.0123	585.480		
		322.6	1.0196	581.395		
		304.5	1.0371	571.429		
		292.8	1.0504	564.334		
		264.2	1.0907	543.478		
		223.4	1.1783	503.018		
		183.8	1.3189	449.438		
		143.3	1.5763	376.081		
		121.7	1.8026	328.839		
		87.2	2.4378	243.132		
		59.9	3.5134	168.719		
	X_{gas} = 0.40	P/bar	V_{rel}	ρ_{global} (kg/m^3)		
		526.4	0.9567	600.240		
		500.5	0.9626	596.303		
		471.5	0.9703	591.716		

Constant mass		441.4	0.9793	586.166
expansions during		413.5	0.9886	580.720
the swelling test		382.8	1.0000	574.053
		373.0	1.0060	570.776
		363.8	1.0122	567.215
		351.9	1.0210	562.430
		325.2	1.0468	548.546
		304.2	1.0684	537.346
		278.9	1.1040	520.021
		244.5	1.1703	490.677
		201.5	1.2860	446.429
		182.8	1.3903	412.882
		151.9	1.5969	359.583
		109.7	2.1155	271.370
		76.9	2.9796	192.678
	$x_{gas} = 0.50$	P/ bar	V_{tot}	ρ_{global} (kg/m^3)
		647.3	0.9381	588.582
		633.0	0.9406	586.854
		621.9	0.9427	585.823
		602.7	0.9465	583.431
		584.0	0.9506	580.720
		545.0	0.9603	575.043
		521.0	0.9671	570.776
		489.5	0.9767	565.291
		479.7	0.9800	563.380
		469.2	0.9835	561.482
		439.8	0.9940	555.556
		429.7	0.9978	553.403
		424.1	1.0000	552.181
		414.2	1.0055	549.149
		406.2	1.0103	546.448
		390.4	1.0199	541.419
		377.0	1.0291	536.481
		362.0	1.0408	530.504
		348.6	1.0527	524.384
		334.2	1.0673	517.331
		318.7	1.0855	508.647
		303.6	1.1048	499.759
		289.6	1.1269	489.956
		280.0	1.1437	482.625
		245.1	1.2205	452.284
		228.0	1.2716	434.216
		172.8	1.5377	359.066
		99.7	2.5148	219.539
Slim tube test	T/K = 376.45; gas: G_{12}	MMP/ bar		
		327		
		initial state	first contact	
First isothermal	injected gas mole number	–	0.67	
and isobaric	(per mole of liquid phase)			
multi-contact test	gas phase mole number	0.000	0.664	
T/K = 376.45; P/ bar	gas phase compressibility factor Z	–	0.960	
= 304.4; gas: G_{12};	gas phase density (kg/m^3)		335.8	
type: reverse;	gas phase MW (g/mol)	–	30.2	
contact number: 1	liquid phase mole number	1.000	1.014	

	liquid phase density (kg/m^3)	644.0	614.0	
	liquid phase MW (g/mol)	78.6	75.3	
	partial volumes (%)	100.0	67.3	
	liquid (L) and gas (G) phase molar composition		L	G
	H_2S		2.68	2.00
	N_2		0.26	0.296
	CO_2		4.51	4.98
	methane		45.13	65.23
	ethane		11.33	11.65
	propane		5.78	5.30
	i-butane		0.96	0.78
	n-butane		2.62	1.95
	i-pentane		0.97	0.64
	n-pentane		1.40	0.89
	hexanes		1.78	1.03
	heptanes		2.02	1.31
	octanes		2.12	1.07
	nonanes		2.04	0.64
	decanes		1.79	0.52
	$C_{11}+$		14.62	1.72
		initial state	first contact	
Second isothermal and isobaric multi-contact test T/K = 376.45; P/bar = 304.4; gas: G_{12}; type: reverse; contact number: 1	injected gas mole number (per mole of liquid phase)	–	6.73	
	gas phase mole number	0.000	7.176	
	gas phase compressibility factor Z	–	0.860	
	gas phase density (kg/m^3)		298.3	
	gas phase MW (g/mol)		25.5	
	liquid phase mole number	1.000	0.559	
	liquid phase density (kg/m^3)	644.0	723.0	
	liquid phase MW (g/mol)	78.6	111.8	
	partial volumes (%)	100.0	11.0	
	liquid (L) and gas (G) phase molar composition		L	G
	H_2S		3.99	3.47
	N_2		1.70	0.10
	CO_2		6.28	7.00
	methane		32.22	64.66
	ethane		11.09	14.50
	propane		5.75	5.72
	i-butane		1.09	0.65
	n-butane		2.11	1.47
	i-pentane		0.63	0.36
	n-pentane		0.74	0.46
	hexanes		2.85	0.25
	heptanes		2.05	0.33
	octanes		2.85	0.20
	nonanes		2.01	0.20
	decanes		1.92	0.15
	$C_{11}+$		22.73	0.56

APPENDIX E

Experimental data in relation with reservoir fluid F_{13} (723 data points)

Isothermal constant mass expansion	T/K = 377.55; P_{sat}/bar = 171.0	P/bar	V_{rel}	ρ_{global} (kg/m^3)	
		351.0	0.9740	741.290	
		302.0	0.9830	736.920	
		271.5	0.9850	733.676	
		231.5	0.9910	729.595	
		214.0	0.9930	727.802	
		193.0	0.9960	725.163	
		182.0	0.9980	724.113	
		171.0	1.0000	722.543	
		169.5	1.0020	720.981	
		163.7	1.0120	713.776	
		154.7	1.0300	701.754	
		140.5	1.0640	678.887	
		126.0	1.1110	650.618	
		112.0	1.1710	616.903	
		99.0	1.2470	579.374	
Isothermal swelling test	T/K = 377.55; gas: C_{13}	100*X_{gas}	P_{sat}/bar	ρ_{sat} (kg/m^3)	V_{excell}
		0.00	171.0	722.5	1.0000
		9.00	194.4	723.2	1.0230
		25.00	224.8	728.4	1.0830
		40.00	261.3	732.1	1.1740
		50.00	295.5	738.0	1.2600
		65.00	380.6	754.8	1.4720
Constant mass expansions during the swelling test	X_{gas} = 0.09	P/bar	V_{rel}	ρ_{global} (kg/m^3)	
		410.3	0.9705	745.212	
		370.1	0.9751	741.730	
		328.7	0.9801	737.898	
		287.6	0.9857	733.730	
		248.6	0.9913	729.554	
		215.0	0.9967	725.637	
		194.4	1.0000	723.223	
		192.5	1.0030	721.033	
		186.4	1.0120	714.694	
		180.0	1.0214	708.065	
		173.6	1.0322	700.673	
		162.4	1.0546	685.824	
		143.8	1.1032	655.609	
		129.4	1.1527	627.471	
		119.1	1.2038	601.793	
		108.6	1.2607	573.691	
		101.0	1.3135	550.630	
		92.2	1.3867	521.567	
	X_{gas} = 0.25	P/bar	V_{rel}	ρ_{global} (kg/m^3)	
		403.3	0.9721	749.232	
		370.1	0.9765	745.879	
		339.1	0.9808	742.611	
		309.1	0.9853	739.262	
		279.1	0.9901	735.619	
		248.9	0.9956	731.582	
		224.8	1.0000	728.385	
		223.1	1.0019	726.956	
		216.0	1.0306	720.721	
		207.1	1.0225	712.301	
		198.1	1.0363	702.839	

Constant mass expansions during the swelling test		188.4	1.0535	691.372
		178.0	1.0757	677.094
		162.5	1.1165	652.401
		148.1	1.1660	624.688
		134.6	1.2253	594.424
		125.8	1.2729	572.213
		118.1	1.3208	551.450
		108.7	1.3931	522.821
	$X_{gas} = 0.40$	P/bar	V_{rel}	ρ_{global} (kg/m^3)
		409.7	0.9707	754.148
		380.9	0.9751	750.751
		350.1	0.9806	746.547
		320.1	0.9860	742.446
		289.8	0.9924	737.626
		263.0	0.9996	732.386
		261.3	1.0000	732.064
		249.8	1.0120	723.380
		240.3	1.0227	715.820
		230.5	1.0349	707.364
		221.9	1.0476	698.812
		213.8	1.0609	690.036
		205.0	1.0776	679.394
		195.3	1.0984	666.445
		183.9	1.1282	648.887
		173.4	1.1606	630.756
		161.7	1.2046	607.718
		151.2	1.2532	584.146
		141.6	1.3043	561.262
		130.5	1.3768	531.717
	$X_{gas} = 0.50$	P/bar	V_{rel}	ρ_{global} (kg/m^3)
		411.9	0.9744	757.404
		390.2	0.9781	754.546
		369.7	0.9820	751.541
		350.3	0.9865	748.111
		331.9	0.9916	745.045
		309.5	0.9962	740.850
		295.5	1.0000	738.062
		292.3	1.0021	736.485
		279.1	1.0119	729.341
		263.6	1.0257	719.528
		254.5	1.0358	712.555
		243.2	1.0495	703.235
		234.8	1.0629	694.348
		227.4	1.0742	687.096
		215.5	1.1003	670.736
		201.6	1.1279	654.322
		189.6	1.1616	635.364
		176.8	1.2083	610.836
		163.0	1.2678	582.140
	$X_{gas} = 0.65$	P/bar	V_{rel}	ρ_{global} (kg/m^3)
		424.1	0.9877	764.234
		401.2	0.9958	759.474
		380.8	0.9999	754.831
		380.6	1.0000	754.774
		361.0	1.0077	749.064
		340.9	1.0182	741.290

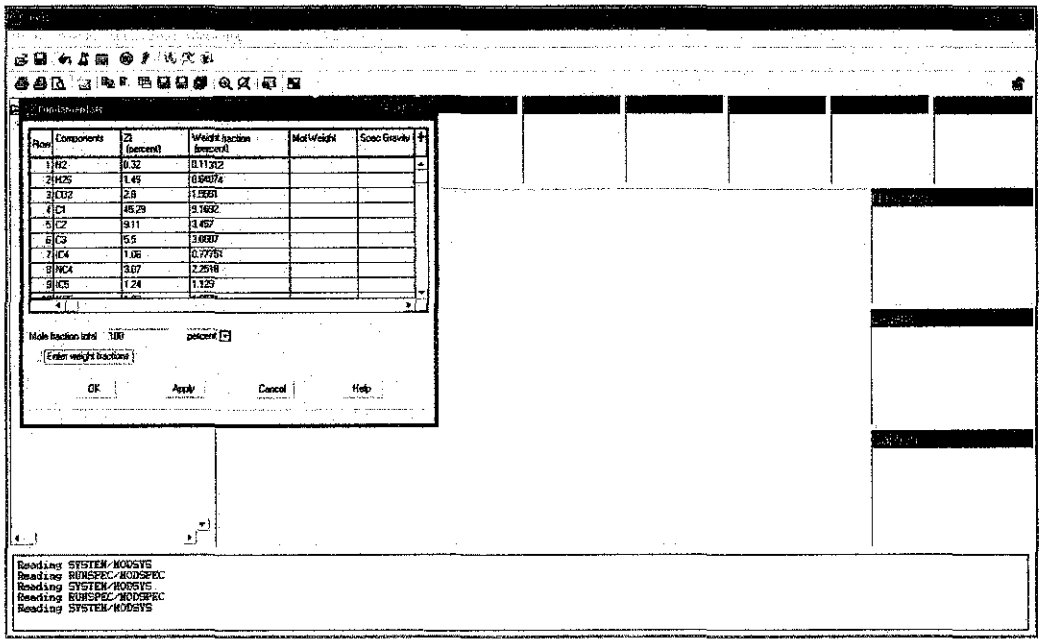
Constant mass expansions during the swelling test		320.2	1.0313	731.850					
		303.5	1.0443	722.752					
		288.1	1.0586	713.012					
		272.4	1.0760	701.459					
		258.5	1.0947	689.513					
		246.6	1.1139	677.599					
		235.5	1.1350	665.026					
		222.2	1.1654	647.710					
		210.0	1.2000	628.970					
		197.3	1.2440	606.759					
		182.0	1.3103	576.037					
Slim tube test	T/K = 377.55 gas: G_{13}	MMP/bar 271							
Isothermal differential vaporization	T/K = 377.55	P/bar	V_{r3}	ρ_{liq} (kg/m^3)	$GOR_{1,G}$	$Z_{1,G}$			
		351.0	0.9748	741.6	–	–			
		302.0	0.9807	736.9	–	–			
		271.5	0.9844	733.8	–	–			
		231.5	0.9904	729.5	–	–			
		214.0	0.9933	727.6	–	–			
		195.0	0.9963	725.1	–	–			
		182.0	0.9985	723.9	–	–			
		171.0	1.0000	722.6	0.0	–			
		142.0	0.9733	732.8	14.8	0.833			
		112.0	0.9496	741.1	29.6	0.844			
		82.5	0.9266	749.3	44.5	0.859			
		52.0	0.9006	759.5	59.6	0.883			
		26.0	0.8776	768.2	73.2	0.911			
		1.0	0.7997	790.2	103.6	1.000			
		initial state	first contact		second contact		third contact		fourth contact
First isothermal and isobaric multi-contact test	injected gas mole number (per mole of liquid phase)	–	2.261		0.995		1.339		1.105
	gas phase mole number	0.0000	1.532		1.190		1.562		1.256
T/K = 377.55;	gas phase compressibility factor Z	0.6331	0.7802		0.7580		0.7075		0.6899
P/bar = 271.0;	gas phase density (kg/m^3)	600.1	481.4		515.9		545.4		565.6
gas: G_{13};	gas phase MW (g/mol)	44.0	43.5		44.1		44.7		45.2
type: reverse;	liquid phase mole number	1.000	1.728		1.533		1.310		1.159
contact number: 4	liquid phase density (kg/m^3)	733.6	782.0		799.0		817.9		828.3
	liquid phase MW (g/mol)	150.2	103.6		109.8		119.0		126.1
	partial volumes (%)	100.0	62.31		67.44		59.81		63.75
	liquid (L) and gas (G) phase molar composition		L	G	L	G	L	G	L	G
	H_2S		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	N_2		0.21	0.58	0.11	0.17	0.07	0.05	0.07	0.01
	CO_2		63.04	77.00	68.83	86.46	71.17	93.60	72.41	95.40
	methane		10.05	13.16	5.17	7.93	2.30	3.14	0.72	1.74
	ethane		1.30	2.10	0.74	0.95	0.38	0.40	0.12	0.28
	propane		1.27	1.31	0.89	0.69	0.59	0.38	0.28	0.36
	i-butane		0.32	0.36	0.23	0.18	0.16	0.09	0.09	0.08
	n-butane		0.96	0.81	0.69	0.50	0.48	0.28	0.27	0.25
	i-pentane		0.40	0.44	0.30	0.19	0.20	0.13	0.15	0.07
	n-pentane		0.64	0.50	0.47	0.32	0.33	0.19	0.24	0.12
	hexanes		0.93	0.74	0.77	0.36	0.62	0.23	0.47	0.22
	heptanes		1.45	0.81	1.18	0.58	1.00	0.31	0.88	0.23

	octanes		1.71	0.40	1.67	0.33	1.64	0.27	1.57	0
	nonanes		1.37	0.45	1.28	0.35	1.18	0.26	1.13	0
	decanes		1.02	0.27	0.96	0.25	0.87	0.21	0.80	0
	$C_{11}+$		15.33	1.07	16.71	0.74	19.01	0.46	20.80	0
		initial state	first contact		second contact		third contact			
Second isothermal and isobaric multi-contact test	injected oil mole number (per mole of gas phase)	-	0.538		0.167		0.077			
	gas phase mole number	1.0000	0.515		0.307		0.211			
T/K = 377.55;	gas phase compressibility factor Z	0.6331	0.7893		0.8612		0.8721			
P/bar = 271.0;	gas phase density (kg/m^3)	600.1	466.3		407.0		388.1			
gas: G_{13};	gas phase MW (g/mol)	44.0	42.6		40.6		39.2			
type: forward;	liquid phase mole number	0.000	1.023		0.375		0.173			
contact number: 3	liquid phase density (kg/m^3)	733.6	775.0		761.0		743.0			
	liquid phase MW (g/mol)	150.2	99.76		93.40		92.10			
	partial volumes (%)	0.00	73.65		60.06		50.10			
	liquid (L) and gas (G) phase molar composition		L	G	L	G	L	G		
	H_2S		0.00	0.00	0.00	0.00	0.00	0.00		
	N_2		0.29	0.72	0.45	1.34	0.62	1.91		
	CO_2		60.65	74.59	51.59	62.71	45.82	54.05		
	methane		12.73	13.94	18.60	21.04	22.72	25.66		
	ethane		1.40	2.95	3.18	4.04	3.71	4.83		
	propane		1.33	1.76	2.18	2.57	2.47	3.24		
	i-butane		0.35	0.45	0.50	0.75	0.55	1.04		
	n-butane		1.03	0.98	1.23	1.72	1.34	2.46		
	i-pentane		0.45	0.52	0.55	0.94	0.59	1.39		
	n-pentane		0.66	0.66	0.82	1.13	0.88	1.60		
	hexanes		1.05	0.76	1.36	1.09	1.44	1.40		
	heptanes		1.47	0.98	1.83	1.45	1.90	1.92		
	octanes		1.72	0.31	1.77	0.28	2.00	0.07		
	nonanes		1.39	0.44	1.74	0.28	1.77	0.08		
	decanes		1.02	0.26	1.15	0.21	1.25	0.07		
	$C_{11}+$		14.46	0.68	13.05	0.45	12.94	0.28		

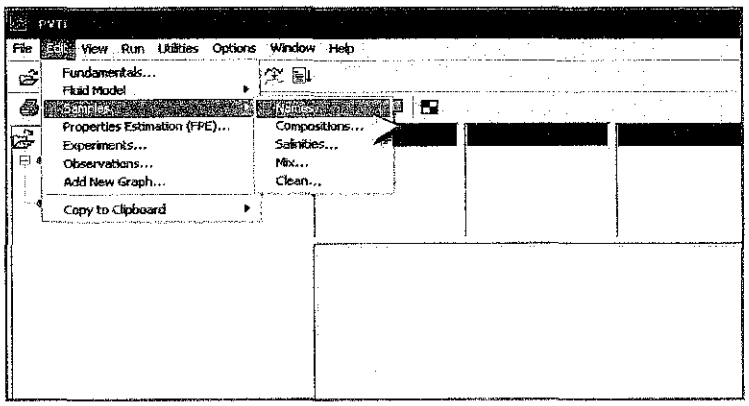
APPENDIX F

Step-by-step multi-contact miscible of gas injection experiment simulation using ECLIPSE PVTi:

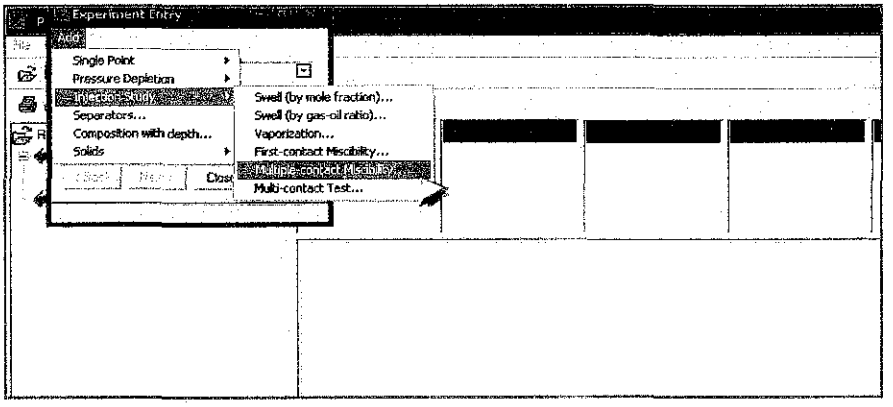
1. Open the ECLIPSE PVTi program and define a reservoir fluid by filling the particulars (components, compositions, molecular weight) in the fundamental window.



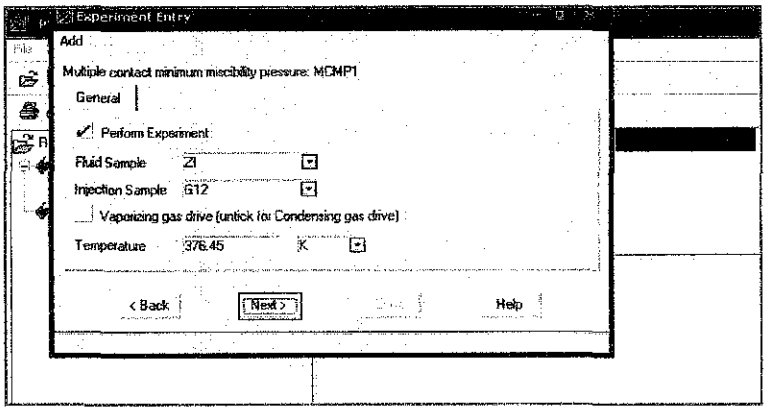
2. Add another fluid (injection fluid) into the system by defining the sample names and composition.



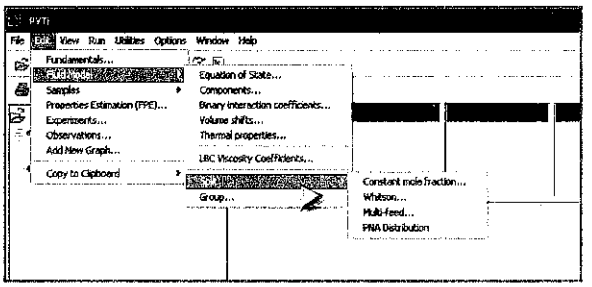
3. Add an experiment (injection study, multiple-contact miscibility).

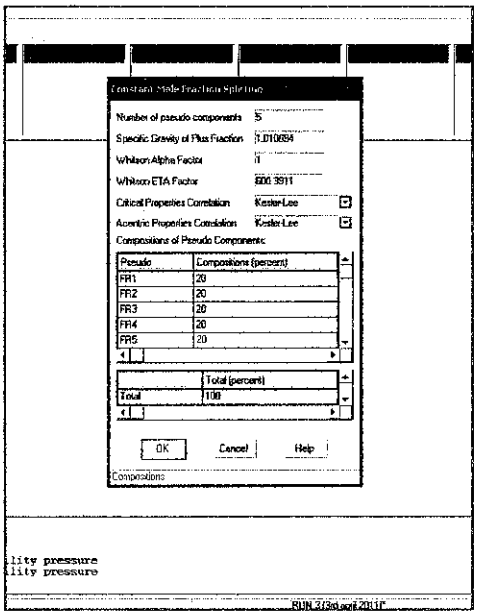


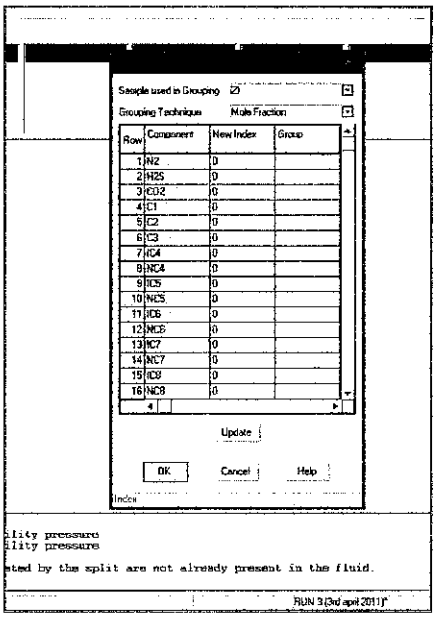
4. Input the required data (for this experiment: temperature).



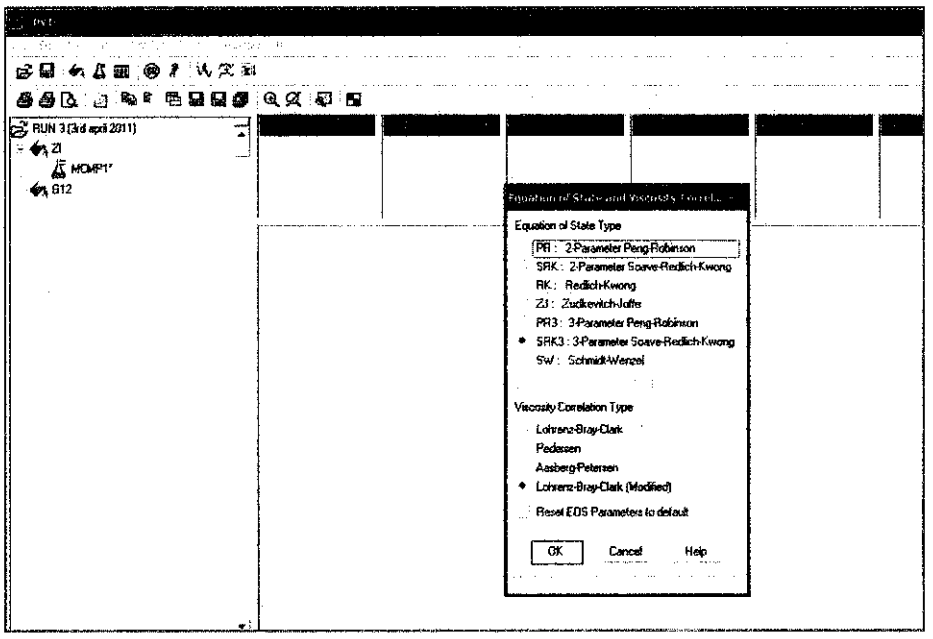
5. Split and group the components and pseudocomponents.



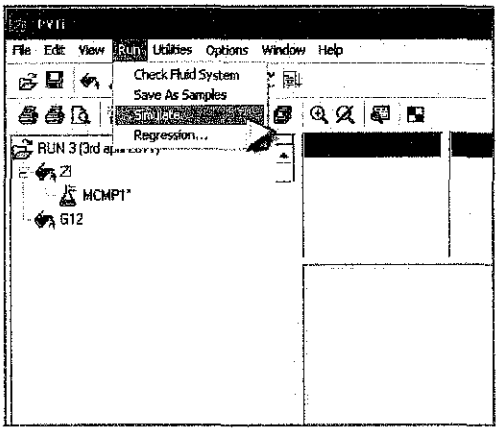




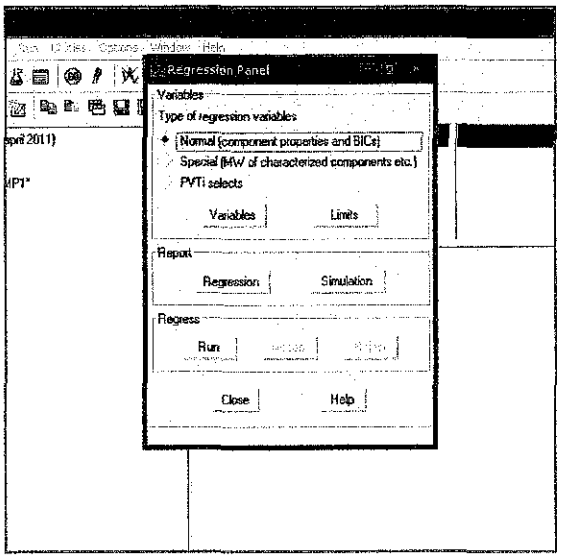
6. Edit the fluid model EOS by choosing appropriate EOS.



7. Run and simulate the experiment.



8. Regress the result by tuning some properties until better result is obtained.



9. Repeat step 5 until 8 for few numbers of pseudocomponents and different EOS model. Lastly, analyze the results obtained.

APPENDIX G

Simulation results for Case 1: Condensing gas drive.

1. PR EOS, 4 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 312.2799
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	80.6733	45.1960
Z-factor	1.3109	0.9715
Viscosity	0.2136	0.0714
Density KG/M3	614.0143	464.1663
Molar Vol M3/KG-ML	0.1314	0.0974

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	2.7617	2.6457	2.7753	1.0490
N2	2	0.2542	0.2558	0.2540	0.9931
CO2	3	5.4146	5.2568	5.4331	1.0335
C1	4	56.0389	53.4539	56.3418	1.0540
C2	5	12.3549	11.3735	12.4700	1.0964
C3	6	5.6425	5.1128	5.7046	1.1158
IC4	7	0.8243	0.7474	0.8333	1.1149
NC4	8	2.0943	1.8807	2.1194	1.1269
IC5	9	0.6973	0.6273	0.7056	1.1247
NC5	10	0.9759	0.8749	0.9877	1.1290
IC6	11	0.5468	0.4885	0.5536	1.1331
NC6	12	0.6109	0.5458	0.6185	1.1332
IC7	13	0.1582	0.1412	0.1601	1.1340
NC7	14	1.1800	1.0543	1.1947	1.1331
IC8	15	0.2124	0.1901	0.2150	1.1311
NC8	16	1.0829	0.9737	1.0957	1.1253
IC9	17	0.2576	0.2325	0.2605	1.1206
NC9	18	0.8676	0.7883	0.8769	1.1124
IC10	19	0.5874	0.5382	0.5932	1.1023
NC10	20	0.3841	0.3539	0.3876	1.0954
C11	21	0.7862	0.7291	0.7930	1.0876
C12	22	0.6417	0.6067	0.6458	1.0644
C13	23	0.5919	0.5672	0.5948	1.0487
C14	24	0.5196	0.5082	0.5210	1.0252
C15	25	0.4519	0.4528	0.4518	0.9977

C16	26	0.3976	0.4098	0.3962	0.9668
C17	27	0.3434	0.3639	0.3410	0.9373
C18	28	0.3118	0.3429	0.3081	0.8987
C19	29	0.2802	0.3168	0.2759	0.8707
FR1	30	0.6823	1.0204	0.6427	0.6298
FR2	31	0.6823	1.1886	0.6230	0.5241
FR3	32	0.6823	1.5961	0.5752	0.3604
FR4	33	0.6823	4.3622	0.2510	0.0575
Composition Total		100.0000	100.0000	100.0000	

2. PR EOS, 5 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 305.9389
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	93.3828	47.0953
Z-factor	2.7350	1.0404
Viscosity	0.0441	0.0638
Density KG/M3	333.7369	442.4444
Molar Vol M3/KG-ML	0.2798	0.1064

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	2.6860	2.4923	2.7025	1.0844
N2	2	0.2581	0.2778	0.2565	0.9231
CO2	3	5.2591	5.1181	5.2711	1.0299
C1	4	55.3996	54.3288	55.4906	1.0214
C2	5	12.1620	10.9975	12.2609	1.1149
C3	6	5.6340	4.8704	5.6989	1.1701
IC4	7	0.8383	0.7129	0.8490	1.1909
NC4	8	2.1524	1.7927	2.1829	1.2177
IC5	9	0.7296	0.5982	0.7408	1.2385
NC5	10	1.0261	0.8328	1.0425	1.2518
IC6	11	0.5862	0.4631	0.5967	1.2883
NC6	12	0.6442	0.5087	0.6557	1.2888
IC7	13	0.1696	0.1323	0.1727	1.3059
NC7	14	1.2579	0.9667	1.2826	1.3267
IC8	15	0.2277	0.1735	0.2323	1.3388
NC8	16	1.1588	0.8761	1.1828	1.3501
IC9	17	0.2761	0.2078	0.2820	1.3570
NC9	18	0.9302	0.6966	0.9500	1.3639

IC10	19	0.6298	0.4700	0.6434	1.3690
NC10	20	0.4118	0.3070	0.4207	1.3705
C11	21	0.8430	0.6279	0.8613	1.3715
C12	22	0.6879	0.5119	0.7029	1.3732
C13	23	0.6347	0.4726	0.6484	1.3721
C14	24	0.5571	0.4161	0.5691	1.3677
C15	25	0.4845	0.3643	0.4947	1.3577
C16	26	0.4263	0.3248	0.4350	1.3393
C17	27	0.3682	0.2842	0.3753	1.3205
C18	28	0.3343	0.2638	0.3403	1.2899
C19	29	0.3004	0.2412	0.3054	1.2659
FR1	30	0.5852	0.6626	0.5787	0.8733
FR2	31	0.5852	0.7209	0.5737	0.7958
FR3	32	0.5852	0.8525	0.5625	0.6598
FR4	33	0.5852	1.2812	0.5261	0.4106
FR5	34	0.5852	6.1527	0.1120	0.0182
Composition Total		100.0000	100.0000	100.0000	

3. PR EOS, 6 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 279.9647
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	133.9840	49.9937
Z-factor	1.6550	0.9171
Viscosity	0.7407	0.0807
Density KG/M3	724.1475	487.6102
Molar Vol M3/KG-ML	0.1850	0.1025

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	2.5540	2.2961	2.5665	1.1178
N2	2	0.2650	0.3067	0.2629	0.8574
CO2	3	4.9877	4.8756	4.9931	1.0241
C1	4	54.2838	53.6137	54.3162	1.0131
C2	5	11.8251	10.0544	11.9108	1.1846
C3	6	5.6192	4.3517	5.6806	1.3054
IC4	7	0.8628	0.6369	0.8737	1.3718
NC4	8	2.2536	1.6059	2.2850	1.4229
IC5	9	0.7860	0.5347	0.7981	1.4928
NC5	10	1.1137	0.7428	1.1316	1.5236
IC6	11	0.6551	0.4110	0.6669	1.6226

NC6	12	0.7022	0.4402	0.7149	1.6241
IC7	13	0.1895	0.1153	0.1931	1.6748
NC7	14	1.3939	0.8163	1.4218	1.7417
IC8	15	0.2544	0.1455	0.2597	1.7848
NC8	16	1.2914	0.7188	1.3191	1.8352
IC9	17	0.3086	0.1687	0.3153	1.8693
NC9	18	1.0394	0.5558	1.0628	1.9123
IC10	19	0.7038	0.3683	0.7200	1.9548
NC10	20	0.4602	0.2382	0.4709	1.9772
C11	21	0.9420	0.4820	0.9642	2.0006
C12	22	0.7687	0.3812	0.7875	2.0658
C13	23	0.7092	0.3456	0.7268	2.1027
C14	24	0.6226	0.2970	0.6383	2.1491
C15	25	0.5414	0.2538	0.5553	2.1875
C16	26	0.4764	0.2216	0.4887	2.2057
C17	27	0.4114	0.1903	0.4221	2.2188
C18	28	0.3735	0.1731	0.3832	2.2142
C19	29	0.3356	0.1562	0.3443	2.2039
FR1	30	0.5451	0.3050	0.5567	1.8253
FR2	31	0.5451	0.3292	0.5555	1.6873
FR3	32	0.5451	0.3871	0.5527	1.4277
FR4	33	0.5448	0.5489	0.5446	0.9922
FR5	34	0.5448	1.3197	0.5073	0.3844
FR6	35	0.5451	11.6129	0.0097	0.0008
Composition Total		100.0000	100.0000	100.0000	

4. PR EOS, 7 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 292.7213
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	107.3044	48.8078
Z-factor	1.4979	0.9445
Viscosity	0.3923	0.0790
Density KG/M3	669.9748	483.2658
Molar Vol M3/KG-ML	0.1602	0.1010

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	2.6385	2.3623	2.6538	1.1234
N2	2	0.2608	0.3038	0.2585	0.8508
CO2	3	5.1613	5.0436	5.1678	1.0246
C1	4	55.0192	55.9782	54.9664	0.9819

C2	5	12.0442	10.7214	12.1170	1.1302
C3	6	5.6321	4.6273	5.6875	1.2291
IC4	7	0.8480	0.6701	0.8578	1.2800
NC4	8	2.1915	1.6755	2.2199	1.3249
IC5	9	0.7511	0.5523	0.7620	1.3797
NC5	10	1.0594	0.7653	1.0756	1.4055
IC6	11	0.6123	0.4182	0.6229	1.4896
NC6	12	0.6662	0.4547	0.6779	1.4909
IC7	13	0.1771	0.1176	0.1804	1.5334
NC7	14	1.2599	0.8083	1.2848	1.5894
IC8	15	0.2378	0.1493	0.2427	1.6256
NC8	16	1.1941	0.7314	1.2196	1.6676
IC9	17	0.2884	0.1737	0.2947	1.6963
NC9	18	0.9715	0.5733	0.9934	1.7327
IC10	19	0.6578	0.3804	0.6731	1.7693
NC10	20	0.4301	0.2461	0.4402	1.7888
C11	21	0.8804	0.4982	0.9015	1.8095
C12	22	0.7185	0.3940	0.7364	1.8688
C13	23	0.6629	0.3570	0.6797	1.9039
C14	24	0.5819	0.3062	0.5971	1.9502
C15	25	0.5060	0.2608	0.5195	1.9921
C16	26	0.4453	0.2266	0.4573	2.0186
C17	27	0.3846	0.1935	0.3951	2.0420
C18	28	0.3491	0.1746	0.3587	2.0548
C19	29	0.3137	0.1566	0.3224	2.0592
FR1	30	0.4367	0.3209	0.4431	1.3807
FR2	31	0.4367	0.3227	0.4430	1.3728
FR3	32	0.4367	0.3334	0.4424	1.3269
FR4	33	0.4367	0.3648	0.4407	1.2081
FR5	34	0.4364	0.4571	0.4353	0.9523
FR6	35	0.4364	0.8733	0.4124	0.4722
FR7	36	0.4364	8.0075	0.0195	0.0024
Composition Total		100.0000	100.0000	100.0000	

5. SRK EOS, 4 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 339.4581
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	76.4705	40.1957
Z-factor	1.3801	1.0038
Viscosity	0.1929	0.0620
Density KG/M3	600.9644	434.3142
Molar Vol M3/KG-ML	0.1272	0.0925

Molar Distributions		Total, Z	Liquid,X	Vapour,Y	K-Values
Components					
Mnemonic	Number	Measured	Calculated	Calculated	Calculated
H2S	1	3.0426	2.9974	3.0452	1.0160
N2	2	0.2397	0.2439	0.2394	0.9817
CO2	3	5.9922	5.9395	5.9953	1.0094
C1	4	58.4133	55.9372	58.5596	1.0469
C2	5	13.0718	11.9730	13.1367	1.0972
C3	6	5.6740	5.0721	5.7096	1.1257
IC4	7	0.7722	0.6861	0.7773	1.1329
NC4	8	1.8788	1.6527	1.8922	1.1449
IC5	9	0.5775	0.5060	0.5817	1.1496
NC5	10	0.7894	0.6887	0.7954	1.1549
IC6	11	0.4002	0.3474	0.4034	1.1612
NC6	12	0.4874	0.4230	0.4912	1.1613
IC7	13	0.1158	0.1003	0.1167	1.1638
NC7	14	0.8906	0.7704	0.8977	1.1652
IC8	15	0.1555	0.1345	0.1567	1.1647
NC8	16	0.8007	0.6949	0.8070	1.1612
IC9	17	0.1885	0.1641	0.1900	1.1580
NC9	18	0.6351	0.5555	0.6398	1.1518
IC10	19	0.4300	0.3787	0.4331	1.1436
NC10	20	0.2812	0.2488	0.2831	1.1378
C11	21	0.5756	0.5121	0.5793	1.1312
C12	22	0.4697	0.4256	0.4723	1.1099
C13	23	0.4333	0.3976	0.4354	1.0951
C14	24	0.3804	0.3561	0.3818	1.0723
C15	25	0.3308	0.3173	0.3316	1.0450
C16	26	0.2911	0.2872	0.2913	1.0143
C17	27	0.2514	0.2552	0.2512	0.9843
C18	28	0.2282	0.2407	0.2275	0.9450
C19	29	0.2051	0.2227	0.2040	0.9163
FR1	30	0.4995	0.6152	0.4927	0.8009
FR2	31	0.4995	0.7635	0.4839	0.6338
FR3	32	0.4995	1.1684	0.4600	0.3937
FR4	33	0.4995	4.9241	0.2381	0.0484
Composition Total		100.0000	100.0000	100.0000	

6. SRK EOS, 5 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 325.0802
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated

Mole Weight	85.0638	39.3597
Z-factor	1.4254	0.9677
Viscosity	0.2320	0.0586
Density KG/M3	619.8294	422.4219
Molar Vol M3/KG-ML	0.1372	0.0932

Molar Distributions		Total, Z	Liquid,X	Vapour,Y	K-Values
Components					
Mnemonic	Number	Measured	Calculated	Calculated	Calculated
H2S	1	3.0740	2.9866	3.0783	1.0307
N2	2	0.2381	0.2490	0.2375	0.9539
CO2	3	6.0568	6.0007	6.0595	1.0098
C1	4	58.6792	56.4701	58.7861	1.0410
C2	5	13.1520	11.8153	13.2167	1.1186
C3	6	5.6775	4.8987	5.7152	1.1667
IC4	7	0.7664	0.6511	0.7720	1.1857
NC4	8	1.8547	1.5515	1.8693	1.2049
IC5	9	0.5641	0.4656	0.5688	1.2216
NC5	10	0.7685	0.6295	0.7753	1.2315
IC6	11	0.3838	0.3093	0.3875	1.2526
NC6	12	0.4736	0.3815	0.4780	1.2529
IC7	13	0.1110	0.0888	0.1121	1.2630
NC7	14	0.8582	0.6802	0.8668	1.2743
IC8	15	0.1491	0.1177	0.1506	1.2802
NC8	16	0.7691	0.6050	0.7771	1.2843
IC9	17	0.1808	0.1420	0.1827	1.2862
NC9	18	0.6091	0.4783	0.6154	1.2866
IC10	19	0.4124	0.3243	0.4167	1.2849
NC10	20	0.2696	0.2124	0.2724	1.2826
C11	21	0.5520	0.4358	0.5576	1.2795
C12	22	0.4505	0.3589	0.4549	1.2673
C13	23	0.4156	0.3336	0.4195	1.2577
C14	24	0.3648	0.2966	0.3681	1.2413
C15	25	0.3172	0.2624	0.3199	1.2193
C16	26	0.2792	0.2361	0.2812	1.1915
C17	27	0.2411	0.2086	0.2427	1.1635
C18	28	0.2189	0.1957	0.2200	1.1243
C19	29	0.1967	0.1804	0.1975	1.0948
FR1	30	0.3832	0.3983	0.3825	0.9603
FR2	31	0.3832	0.4628	0.3794	0.8198
FR3	32	0.3832	0.6005	0.3727	0.6207
FR4	33	0.3832	1.0258	0.3521	0.3433
FR5	34	0.3832	5.9470	0.1140	0.0192
Composition Total		100.0000	100.0000	100.0000	

7. SRK EOS, 6 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500

Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 320.9066
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	91.3274	38.6558
Z-factor	1.4779	0.9547
Viscosity	0.2676	0.0567
Density KG/M3	633.5897	415.1250
Molar Vol M3/KG-ML	0.1441	0.0931

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	3.1095	2.9812	3.1145	1.0447
N2	2	0.2362	0.2534	0.2356	0.9295
CO2	3	6.1297	6.0690	6.1321	1.0104
C1	4	58.9789	57.1456	59.0501	1.0333
C2	5	13.2425	11.7256	13.3014	1.1344
C3	6	5.6815	4.7627	5.7172	1.2004
IC4	7	0.7598	0.6215	0.7652	1.2311
NC4	8	1.8275	1.4650	1.8415	1.2570
IC5	9	0.5489	0.4303	0.5535	1.2862
NC5	10	0.7450	0.5778	0.7515	1.3006
IC6	11	0.3653	0.2758	0.3688	1.3373
NC6	12	0.4580	0.3456	0.4623	1.3378
IC7	13	0.1057	0.0787	0.1067	1.3560
NC7	14	0.8216	0.6023	0.8301	1.3783
IC8	15	0.1419	0.1031	0.1434	1.3914
NC8	16	0.7335	0.5279	0.7415	1.4047
IC9	17	0.1721	0.1232	0.1740	1.4129
NC9	18	0.5797	0.4124	0.5862	1.4215
IC10	19	0.3925	0.2779	0.3970	1.4283
NC10	20	0.2566	0.1814	0.2596	1.4307
C11	21	0.5254	0.3709	0.5314	1.4327
C12	22	0.4288	0.3024	0.4337	1.4340
C13	23	0.3955	0.2793	0.4001	1.4325
C14	24	0.3472	0.2461	0.3512	1.4266
C15	25	0.3019	0.2158	0.3053	1.4144
C16	26	0.2657	0.1926	0.2685	1.3940
C17	27	0.2295	0.1689	0.2318	1.3723
C18	28	0.2083	0.1572	0.2103	1.3382
C19	29	0.1872	0.1440	0.1889	1.3113
FR1	30	0.3040	0.2647	0.3055	1.1543
FR2	31	0.3040	0.2930	0.3044	1.0390
FR3	32	0.3040	0.3464	0.3024	0.8728
FR4	33	0.3038	0.4673	0.2975	0.6366
FR5	34	0.3038	0.8867	0.2812	0.3171
FR6	35	0.3040	6.7038	0.0557	0.0083
Composition Total		100.0000	100.0000	100.0000	

8. SRK EOS, 7 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 333.7298
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	97.1985	38.6778
Z-factor	1.5905	0.9792
Viscosity	0.3252	0.0583
Density KG/M3	651.6140	421.1692
Molar Vol M3/KG-ML	0.1492	0.0918

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	3.1135	2.9204	3.1198	1.0683
N2	2	0.2364	0.2642	0.2355	0.8912
CO2	3	6.1377	6.0728	6.1398	1.0110
C1	4	59.0422	58.1214	59.0725	1.0164
C2	5	13.2575	11.5636	13.3131	1.1513
C3	6	5.6868	4.5985	5.7225	1.2444
IC4	7	0.7603	0.5918	0.7658	1.2941
NC4	8	1.8282	1.3848	1.8428	1.3308
IC5	9	0.5489	0.4010	0.5538	1.3810
NC5	10	0.7449	0.5358	0.7518	1.4030
IC6	11	0.3651	0.2513	0.3688	1.4674
NC6	12	0.4579	0.3150	0.4626	1.4684
IC7	13	0.1056	0.0711	0.1067	1.5014
NC7	14	0.7513	0.4920	0.7598	1.5442
IC8	15	0.1418	0.0913	0.1435	1.5713
NC8	16	0.7121	0.4497	0.7207	1.6024
IC9	17	0.1720	0.1073	0.1741	1.6232
NC9	18	0.5793	0.3558	0.5866	1.6488
IC10	19	0.3922	0.2374	0.3973	1.6736
NC10	20	0.2565	0.1541	0.2598	1.6864
C11	21	0.5250	0.3130	0.5320	1.6996
C12	22	0.4284	0.2508	0.4343	1.7317
C13	23	0.3953	0.2290	0.4007	1.7496
C14	24	0.3470	0.1988	0.3518	1.7702
C15	25	0.3017	0.1715	0.3060	1.7843
C16	26	0.2655	0.1508	0.2693	1.7862
C17	27	0.2293	0.1303	0.2326	1.7845
C18	28	0.2082	0.1193	0.2111	1.7701

C19	29	0.1871	0.1081	0.1897	1.7553
FR1	30	0.2604	0.1709	0.2634	1.5408
FR2	31	0.2604	0.1807	0.2630	1.4555
FR3	32	0.2604	0.1993	0.2624	1.3169
FR4	33	0.2604	0.2372	0.2612	1.1009
FR5	34	0.2602	0.3315	0.2579	0.7780
FR6	35	0.2602	0.7172	0.2452	0.3419
FR7	36	0.2602	7.5124	0.0220	0.0029
Composition Total		100.0000	100.0000	100.0000	

9. SW EOS, 4 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Modified LBC Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 293.5411
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	114.7466	49.2223
Z-factor	2.4890	1.0128
Viscosity	0.0690	0.0678
Density KG/M3	432.3604	455.8188
Molar Vol M3/KG-ML	0.2654	0.1080

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	2.5323	2.3516	2.5478	1.0834
N2	2	0.2661	0.2877	0.2642	0.9185
CO2	3	4.9431	4.8210	4.9535	1.0275
C1	4	54.1003	52.0535	54.2755	1.0427
C2	5	11.7697	10.2585	11.8990	1.1599
C3	6	5.6168	4.6190	5.7022	1.2345
IC4	7	0.8668	0.6956	0.8815	1.2673
NC4	8	2.2703	1.7785	2.3124	1.3002
IC5	9	0.7952	0.6089	0.8112	1.3321
NC5	10	1.1281	0.8533	1.1516	1.3496
IC6	11	0.6664	0.4876	0.6817	1.3979
NC6	12	0.7117	0.5206	0.7281	1.3986
IC7	13	0.1928	0.1388	0.1974	1.4218
NC7	14	1.4162	1.0010	1.4518	1.4503
IC8	15	0.2588	0.1810	0.2655	1.4671
NC8	16	1.3132	0.9085	1.3478	1.4835
IC9	17	0.3139	0.2158	0.3223	1.4936
NC9	18	1.0574	0.7222	1.0861	1.5038
IC10	19	0.7159	0.4866	0.7356	1.5117

NC10	20	0.4681	0.3176	0.4810	1.5142
C11	21	0.9583	0.6495	0.9847	1.5161
C12	22	0.7820	0.5292	0.8037	1.5187
C13	23	0.7214	0.4887	0.7414	1.5169
C14	24	0.6333	0.4309	0.6506	1.5099
C15	25	0.5507	0.3783	0.5655	1.4947
C16	26	0.4846	0.3386	0.4971	1.4682
C17	27	0.4185	0.2977	0.4289	1.4405
C18	28	0.3800	0.2784	0.3887	1.3964
C19	29	0.3414	0.2561	0.3488	1.3618
FR1	30	0.8316	0.7586	0.8378	1.1044
FR2	31	0.8316	0.9680	0.8199	0.8470
FR3	32	0.8316	1.7231	0.7553	0.4383
FR4	33	0.8316	9.5955	0.0817	0.0085
Composition Total		100.0000	100.0000	100.0000	

10. SW EOS, 5 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Modified LBC Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 290.2692
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	126.2252	49.7548
Z-factor	2.8792	1.0102
Viscosity	0.0631	0.0682
Density KG/M3	406.5759	456.7606
Molar Vol M3/KG-ML	0.3105	0.1089

Molar Distributions Components		Total, Z	Liquid,X	Vapour,Y	K-Values
Mnemonic	Number	Measured	Calculated	Calculated	Calculated
H2S	1	2.5390	2.3108	2.5532	1.1049
N2	2	0.2657	0.2998	0.2636	0.8793
CO2	3	4.9568	4.8419	4.9640	1.0252
C1	4	54.1569	52.9455	54.2322	1.0243
C2	5	11.7868	10.1151	11.8906	1.1755
C3	6	5.6176	4.4521	5.6900	1.2780
IC4	7	0.8656	0.6602	0.8783	1.3304
NC4	8	2.2652	1.6747	2.3018	1.3745
IC5	9	0.7924	0.5647	0.8065	1.4283
NC5	10	1.1237	0.7873	1.1446	1.4537
IC6	11	0.6629	0.4418	0.6766	1.5316
NC6	12	0.7088	0.4720	0.7235	1.5328
IC7	13	0.1917	0.1246	0.1959	1.5718

NC7	14	1.4093	0.8888	1.4417	1.6221
IC8	15	0.2575	0.1594	0.2636	1.6537
NC8	16	1.3065	0.7925	1.3384	1.6889
IC9	17	0.3123	0.1869	0.3201	1.7122
NC9	18	1.0518	0.6199	1.0787	1.7401
IC10	19	0.7122	0.4137	0.7307	1.7665
NC10	20	0.4657	0.2686	0.4779	1.7795
C11	21	0.9532	0.5459	0.9785	1.7926
C12	22	0.7779	0.4372	0.7991	1.8276
C13	23	0.7177	0.3996	0.7374	1.8455
C14	24	0.6300	0.3472	0.6476	1.8652
C15	25	0.5478	0.3002	0.5632	1.8760
C16	26	0.4821	0.2650	0.4956	1.8700
C17	27	0.4164	0.2300	0.4279	1.8606
C18	28	0.3780	0.2119	0.3883	1.8328
C19	29	0.3397	0.1930	0.3488	1.8075
FR1	30	0.6618	0.4554	0.6746	1.4815
FR2	31	0.6618	0.5230	0.6704	1.2819
FR3	32	0.6618	0.7040	0.6592	0.9363
FR4	33	0.6618	1.4713	0.6115	0.4156
FR5	34	0.6618	10.8962	0.0260	0.0024
Composition Total		100.0000	100.0000	100.0000	

11. SW EOS, 6 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Aasberg-Petersen Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 279.9647
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	133.9840	49.9937
Z-factor	3.1074	0.9885
Viscosity	0.9620	0.1384
Density KG/M3	385.6749	452.3915
Molar Vol M3/KG-ML	0.3474	0.1105

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
H2S	1	2.5540	2.2961	2.5665	1.1178
N2	2	0.2650	0.3067	0.2629	0.8574
CO2	3	4.9877	4.8756	4.9931	1.0241
C1	4	54.2838	53.6137	54.3162	1.0131
C2	5	11.8251	10.0544	11.9108	1.1846
C3	6	5.6192	4.3517	5.6806	1.3054
IC4	7	0.8628	0.6369	0.8737	1.3718

NC4	8	2.2536	1.6059	2.2850	1.4229
IC5	9	0.7860	0.5347	0.7981	1.4928
NC5	10	1.1137	0.7428	1.1316	1.5236
IC6	11	0.6551	0.4110	0.6669	1.6226
NC6	12	0.7022	0.4402	0.7149	1.6241
IC7	13	0.1895	0.1153	0.1931	1.6748
NC7	14	1.3939	0.8163	1.4218	1.7417
IC8	15	0.2544	0.1455	0.2597	1.7848
NC8	16	1.2914	0.7188	1.3191	1.8352
IC9	17	0.3086	0.1687	0.3153	1.8693
NC9	18	1.0394	0.5558	1.0628	1.9123
IC10	19	0.7038	0.3683	0.7200	1.9548
NC10	20	0.4602	0.2382	0.4709	1.9772
C11	21	0.9420	0.4820	0.9642	2.0006
C12	22	0.7687	0.3812	0.7875	2.0658
C13	23	0.7092	0.3456	0.7268	2.1027
C14	24	0.6226	0.2970	0.6383	2.1491
C15	25	0.5414	0.2538	0.5553	2.1875
C16	26	0.4764	0.2216	0.4887	2.2057
C17	27	0.4114	0.1903	0.4221	2.2188
C18	28	0.3735	0.1731	0.3832	2.2142
C19	29	0.3356	0.1562	0.3443	2.2039
FR1	30	0.5451	0.3050	0.5567	1.8253
FR2	31	0.5451	0.3292	0.5555	1.6873
FR3	32	0.5451	0.3871	0.5527	1.4277
FR4	33	0.5448	0.5489	0.5446	0.9922
FR5	34	0.5448	1.3197	0.5073	0.3844
FR6	35	0.5451	11.6129	0.0097	0.0008
Composition Total		100.0000	100.0000	100.0000	

12. SW EOS, 7 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Aasberg-Petersen Viscosity Correlation
Specified temperature Deg K 376.4500
Condensing drive injection gas G12
Multiple contact miscibility pressure BARSA 279.9446
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	139.9505	49.7523
Z-factor	3.3992	0.9916
Viscosity	0.9822	0.1390
Density KG/M3	368.2427	448.7443
Molar Vol M3/KG-ML	0.3800	0.1109

Molar Distributions Components	Total, Z	Liquid,X	Vapour,Y	K-Values
Mnemonic Number	Measured	Calculated	Calculated	Calculated

H2S	1	2.5857	2.2967	2.5969	1.1307
N2	2	0.2636	0.3114	0.2617	0.8406
CO2	3	5.0526	4.9343	5.0572	1.0249
C1	4	54.5715	54.3043	54.5818	1.0051
C2	5	11.9092	10.0345	11.9819	1.1941
C3	6	5.6261	4.2670	5.6788	1.3309
IC4	7	0.8577	0.6150	0.8672	1.4100
NC4	8	2.2319	1.5394	2.2588	1.4673
IC5	9	0.7736	0.5052	0.7840	1.5520
NC5	10	1.0944	0.6989	1.1098	1.5878
IC6	11	0.6398	0.3808	0.6498	1.7065
NC6	12	0.6894	0.4099	0.7002	1.7083
IC7	13	0.1851	0.1063	0.1881	1.7701
NC7	14	1.3165	0.7230	1.3396	1.8527
IC8	15	0.2485	0.1327	0.2530	1.9070
NC8	16	1.2478	0.6446	1.2712	1.9722
IC9	17	0.3014	0.1523	0.3072	2.0171
NC9	18	1.0152	0.4989	1.0352	2.0751
IC10	19	0.6873	0.3286	0.7013	2.1339
NC10	20	0.4494	0.2118	0.4586	2.1659
C11	21	0.9200	0.4269	0.9391	2.1999
C12	22	0.7508	0.3340	0.7670	2.2966
C13	23	0.6926	0.3007	0.7078	2.3539
C14	24	0.6080	0.2559	0.6217	2.4293
C15	25	0.5287	0.2165	0.5408	2.4985
C16	26	0.4653	0.1871	0.4761	2.5448
C17	27	0.4018	0.1591	0.4112	2.5846
C18	28	0.3648	0.1431	0.3734	2.6089
C19	29	0.3278	0.1282	0.3356	2.6181
FR1	30	0.4564	0.2137	0.4658	2.1799
FR2	31	0.4564	0.2221	0.4654	2.0957
FR3	32	0.4564	0.2430	0.4646	1.9121
FR4	33	0.4564	0.2933	0.4627	1.5774
FR5	34	0.4560	0.4397	0.4567	1.0386
FR6	35	0.4560	1.2211	0.4264	0.3492
FR7	36	0.4560	12.1204	0.0035	0.0003
Composition Total		100.0000	100.0000	100.0000	

APPENDIX H

Simulation results for Case 1: Condensing gas drive.

1. PR EOS, 4 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 263.6850
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	148.8790	57.9093
Z-factor	1.2907	0.6390
Viscosity	0.5507	0.0785
Density KG/M3	748.4683	588.0805
Molar Vol M3/KG-ML	0.1989	0.0985

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.4918	0.6468	0.4864	0.7520
CO2	2	64.7541	59.5939	64.9309	1.0896
C1	3	14.7455	17.1713	14.6624	0.8539
C2	4	2.1508	2.1270	2.1516	1.0115
C3	5	1.6481	1.4466	1.6550	1.1441
IC4	6	0.4336	0.3572	0.4362	1.2214
NC4	7	1.1398	0.8961	1.1482	1.2812
IC5	8	0.5342	0.3900	0.5391	1.3821
NC5	9	0.7364	0.5231	0.7437	1.4218
IC6	10	0.5035	0.3270	0.5096	1.5583
NC6	11	0.5703	0.3698	0.5772	1.5607
IC7	12	0.2188	0.1339	0.2217	1.6557
NC7	13	1.2502	0.7226	1.2682	1.7551
IC8	14	0.3280	0.1775	0.3331	1.8770
NC8	15	1.0683	0.5599	1.0857	1.9391
IC9	16	0.3515	0.1757	0.3575	2.0353
NC9	17	0.8527	0.4089	0.8679	2.1223
IC10	18	0.5295	0.2385	0.5394	2.2617
NC10	19	0.3272	0.1443	0.3334	2.3114
C11	20	0.9611	0.4186	0.9797	2.3404
C12	21	0.8217	0.3303	0.8385	2.5384
C13	22	0.7027	0.2591	0.7179	2.7707
C14	23	0.7027	0.2349	0.7187	3.0601
C15	24	0.7404	0.2235	0.7581	3.3921
C16	25	0.6158	0.1648	0.6313	3.8315

C17	26	0.5565	0.1338	0.5710	4.2691
C18	27	0.3397	0.0754	0.3488	4.6284
C19	28	0.4313	0.0913	0.4429	4.8509
FR1	29	0.3735	0.0982	0.3829	3.8990
FR2	30	0.3735	0.0888	0.3833	4.3172
FR3	31	0.3735	0.1938	0.3797	1.9589
FR4	32	0.3735	11.2775	2.6078E-06	2.3124E-07
Composition Total		100.0000	100.0000	100.0000	

2. PR EOS, 5 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 253.8550
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	157.8961	58.2643
Z-factor	1.3034	0.6205
Viscosity	0.5772	0.0767
Density KG/M3	748.1030	579.8453
Molar Vol M3/KG-ML	0.2111	0.1005

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.4885	0.6709	0.4838	0.7210
CO2	2	64.9841	60.3323	65.1061	1.0791
C1	3	14.6493	17.2465	14.5811	0.8455
C2	4	2.1367	2.0999	2.1377	1.0180
C3	5	1.6373	1.3968	1.6436	1.1767
IC4	6	0.4308	0.3387	0.4332	1.2792
NC4	7	1.1324	0.8450	1.1399	1.3490
IC5	8	0.5307	0.3615	0.5351	1.4800
NC5	9	0.7316	0.4827	0.7381	1.5292
IC6	10	0.5003	0.2966	0.5056	1.7044
NC6	11	0.5666	0.3354	0.5726	1.7075
IC7	12	0.2173	0.1201	0.2199	1.8309
NC7	13	1.2420	0.6409	1.2578	1.9624
IC8	14	0.3258	0.1553	0.3303	2.1275
NC8	15	1.0613	0.4863	1.0764	2.2136
IC9	16	0.3492	0.1509	0.3544	2.3483
NC9	17	0.8471	0.3479	0.8602	2.4726
IC10	18	0.5260	0.1998	0.5346	2.6753
NC10	19	0.3250	0.1202	0.3304	2.7488
C11	20	0.9548	0.3477	0.9707	2.7919

C12	21	0.8163	0.2689	0.8307	3.0895
C13	22	0.6981	0.2062	0.7110	3.4477
C14	23	0.6981	0.1822	0.7116	3.9062
C15	24	0.7355	0.1685	0.7504	4.4524
C16	25	0.6118	0.1197	0.6247	5.2175
C17	26	0.5529	0.0939	0.5650	6.0175
C18	27	0.3375	0.0515	0.3450	6.7045
C19	28	0.4285	0.0613	0.4381	7.1410
FR1	29	0.2969	0.0505	0.3033	6.0115
FR2	30	0.2969	0.0389	0.3036	7.7995
FR3	31	0.2969	0.0387	0.3036	7.8559
FR4	32	0.2969	0.1342	0.3011	2.2434
FR5	33	0.2969	11.6098	1.3839E-08	1.1920E-09
Composition Total		100.0000	100.0000	100.0000	

3. PR EOS, 6 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 253.2040
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	165.1781	58.4895
Z-factor	1.3529	0.6222
Viscosity	0.6218	0.0766
Density KG/M3	751.4689	578.6170
Molar Vol M3/KG-ML	0.2198	0.1011

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.4855	0.6918	0.4811	0.6955
CO2	2	65.2038	60.7721	65.2979	1.0745
C1	3	14.5573	17.4799	14.4953	0.8293
C2	4	2.1233	2.0681	2.1245	1.0273
C3	5	1.6270	1.3479	1.6329	1.2115
IC4	6	0.4281	0.3214	0.4304	1.3388
NC4	7	1.1253	0.7979	1.1322	1.4190
IC5	8	0.5273	0.3361	0.5314	1.5810
NC5	9	0.7270	0.4469	0.7330	1.6401
IC6	10	0.4971	0.2703	0.5019	1.8568
NC6	11	0.5630	0.3055	0.5685	1.8606
IC7	12	0.2160	0.1083	0.2183	2.0148
NC7	13	1.2342	0.5722	1.2483	2.1816
IC8	14	0.3238	0.1369	0.3277	2.3947

NC8	15	1.0547	0.4258	1.0680	2.5080
IC9	16	0.3470	0.1309	0.3516	2.6866
NC9	17	0.8418	0.2990	0.8533	2.8539
IC10	18	0.5227	0.1694	0.5302	3.1307
NC10	19	0.3230	0.1014	0.3277	3.2324
C11	20	0.9488	0.2924	0.9627	3.2923
C12	21	0.8112	0.2220	0.8237	3.7101
C13	22	0.6937	0.1669	0.7049	4.2238
C14	23	0.6937	0.1440	0.7054	4.8973
C15	24	0.7309	0.1299	0.7437	5.7243
C16	25	0.6080	0.0893	0.6190	6.9331
C17	26	0.5494	0.0679	0.5597	8.2472
C18	27	0.3354	0.0363	0.3418	9.4157
C19	28	0.4258	0.0426	0.4339	10.1742
FR1	29	0.2459	0.0291	0.2505	8.6034
FR2	30	0.2459	0.0211	0.2507	11.8786
FR3	31	0.2459	0.0167	0.2507	15.0055
FR4	32	0.2459	0.0191	0.2507	13.1560
FR5	33	0.2457	0.1150	0.2485	2.1613
FR6	34	0.2457	11.8258	3.4517E-11	2.9188E-12
Composition Total		100.0000	100.0000	100.0000	

4. PR EOS, 7 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 246.9454
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	165.2673	58.4210
Z-factor	1.3279	0.6092
Viscosity	0.5572	0.0744
Density KG/M3	741.2282	571.0767
Molar Vol M3/KG-ML	0.2230	0.1023

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.4752	0.6914	0.4712	0.6815
CO2	2	65.9406	61.7161	66.0184	1.0697
C1	3	14.2491	17.6039	14.1873	0.8059
C2	4	2.0784	2.0159	2.0795	1.0316
C3	5	1.5926	1.2973	1.5980	1.2318
IC4	6	0.4190	0.3060	0.4211	1.3763
NC4	7	1.1014	0.7576	1.1078	1.4622

IC5	8	0.5162	0.3158	0.5199	1.6459
NC5	9	0.7116	0.4189	0.7170	1.7115
IC6	10	0.4866	0.2509	0.4909	1.9563
NC6	11	0.5511	0.2836	0.5560	1.9606
IC7	12	0.2114	0.0999	0.2135	2.1361
NC7	13	1.2081	0.5244	1.2207	2.3278
IC8	14	0.3169	0.1244	0.3205	2.5757
NC8	15	1.0323	0.3854	1.0443	2.7092
IC9	16	0.3397	0.1177	0.3438	2.9207
NC9	17	0.8240	0.2673	0.8342	3.1210
IC10	18	0.5116	0.1500	0.5183	3.4556
NC10	19	0.3162	0.0895	0.3203	3.5798
C11	20	0.9287	0.2576	0.9411	3.6531
C12	21	0.7940	0.1932	0.8051	4.1678
C13	22	0.6790	0.1432	0.6889	4.8102
C14	23	0.6790	0.1216	0.6893	5.6664
C15	24	0.7154	0.1078	0.7266	6.7399
C16	25	0.5951	0.0724	0.6047	8.3568
C17	26	0.5378	0.0538	0.5467	10.1640
C18	27	0.3283	0.0283	0.3338	11.8114
C19	28	0.4168	0.0329	0.4238	12.8973
FR1	29	0.2063	0.0195	0.2098	10.7440
FR2	30	0.2063	0.0139	0.2099	15.1166
FR3	31	0.2063	0.0101	0.2099	20.7321
FR4	32	0.2063	0.0084	0.2100	25.0527
FR5	33	0.2062	0.0110	0.2098	19.0727
FR6	34	0.2062	0.1079	0.2080	1.9271
FR7	35	0.2062	11.4024	2.2339E-13	1.9591E-14
Composition Total		100.0000	100.0000	100.0000	

5. SRK EOS, 4 psudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 272.8359
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	112.6059	56.0291
Z-factor	1.1338	0.6540
Viscosity	0.2151	0.0725
Density KG/M3	673.4180	580.8822
Molar Vol M3/KG-ML	0.1672	0.0965

Molar Distributions Components	Total, Z	Liquid,X	Vapour,Y	K-Values
Mnemonic Number	Measured	Calculated	Calculated	Calculated

N2	1	0.4212	0.7490	0.4062	0.5424
CO2	2	69.8126	65.6654	70.0015	1.0660
C1	3	12.6292	15.5010	12.4984	0.8063
C2	4	1.8421	1.9409	1.8376	0.9468
C3	5	1.4115	1.3724	1.4133	1.0298
IC4	6	0.3714	0.3413	0.3728	1.0921
NC4	7	0.9762	0.8623	0.9814	1.1382
IC5	8	0.4575	0.3794	0.4610	1.2152
NC5	9	0.6307	0.5102	0.6362	1.2471
IC6	10	0.4313	0.3189	0.4364	1.3686
NC6	11	0.4884	0.3606	0.4943	1.3708
IC7	12	0.1874	0.1312	0.1899	1.4472
NC7	13	1.0708	0.7093	1.0872	1.5329
IC8	14	0.2809	0.1753	0.2857	1.6295
NC8	15	0.9150	0.5527	0.9315	1.6854
IC9	16	0.3011	0.1741	0.3069	1.7621
NC9	17	0.7303	0.4050	0.7451	1.8397
IC10	18	0.4535	0.2366	0.4633	1.9582
NC10	19	0.2802	0.1432	0.2865	2.0002
C11	20	0.8231	0.4143	0.8418	2.0316
C12	21	0.7038	0.3274	0.7209	2.2019
C13	22	0.6018	0.2562	0.6176	2.4103
C14	23	0.6018	0.2310	0.6187	2.6783
C15	24	0.6341	0.2178	0.6531	2.9983
C16	25	0.5275	0.1579	0.5443	3.4481
C17	26	0.4767	0.1255	0.4927	3.9268
C18	27	0.2910	0.0693	0.3011	4.3460
C19	28	0.3694	0.0828	0.3824	4.6182
FR1	29	0.3199	0.0806	0.3308	4.1055
FR2	30	0.3199	0.0650	0.3315	5.1017
FR3	31	0.3199	0.1044	0.3297	3.1592
FR4	32	0.3199	7.3390	3.9756E-05	5.4171E-06
Composition Total		100.0000	100.0000	100.0000	

6. SRK EOS, 5 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 265.4422
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	121.3832	55.7146
Z-factor	1.1730	0.6393
Viscosity	0.2343	0.0695
Density KG/M3	677.2786	570.4079
Molar Vol M3/KG-ML	0.1792	0.0977

Molar Distributions		Total, Z	Liquid,X	Vapour,Y	K-Values
Components					
Mnemonic	Number	Measured	Calculated	Calculated	Calculated
N2	1	0.3991	0.7386	0.3883	0.5258
CO2	2	71.3941	67.0756	71.5313	1.0664
C1	3	11.9676	14.9772	11.8720	0.7927
C2	4	1.7456	1.8292	1.7429	0.9529
C3	5	1.3376	1.2703	1.3397	1.0547
IC4	6	0.3519	0.3113	0.3532	1.1345
NC4	7	0.9251	0.7828	0.9296	1.1876
IC5	8	0.4335	0.3394	0.4365	1.2863
NC5	9	0.5977	0.4546	0.6022	1.3248
IC6	10	0.4087	0.2799	0.4128	1.4747
NC6	11	0.4628	0.3164	0.4675	1.4773
IC7	12	0.1776	0.1141	0.1796	1.5739
NC7	13	1.0147	0.6106	1.0275	1.6826
IC8	14	0.2662	0.1491	0.2699	1.8096
NC8	15	0.8670	0.4672	0.8797	1.8829
IC9	16	0.2853	0.1458	0.2897	1.9868
NC9	17	0.6920	0.3363	0.7033	2.0914
IC10	18	0.4297	0.1939	0.4372	2.2553
NC10	19	0.2655	0.1168	0.2703	2.3144
C11	20	0.7800	0.3369	0.7941	2.3567
C12	21	0.6669	0.2617	0.6798	2.5978
C13	22	0.5703	0.2009	0.5820	2.8976
C14	23	0.5703	0.1771	0.5828	3.2902
C15	24	0.6009	0.1630	0.6148	3.7711
C16	25	0.4998	0.1145	0.5121	4.4735
C17	26	0.4517	0.0883	0.4632	5.2445
C18	27	0.2757	0.0477	0.2830	5.9384
C19	28	0.3500	0.0562	0.3594	6.3956
FR1	29	0.2425	0.0433	0.2488	5.7461
FR2	30	0.2425	0.0315	0.2492	7.9206
FR3	31	0.2425	0.0273	0.2494	9.1320
FR4	32	0.2425	0.0644	0.2482	3.8557
FR5	33	0.2425	7.8782	5.7256E-07	7.2676E-08
Composition Total		100.0000	100.0000	100.0000	

7. SRK EOS, 6 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 260.3897
(to 1 atmosphere accuracy)

Fluid properties	Liquid	Vapour
	Calculated	Calculated

Mole Weight	125.9190	55.7611
Z-factor	1.1923	0.6313
Viscosity	0.2363	0.0681
Density KG/M3	674.1885	563.8873
Molar Vol M3/KG-ML	0.1868	0.0989

Molar Distributions		Total, Z	Liquid,X	Vapour,Y	K-Values
Components					
Mnemonic	Number	Measured	Calculated	Calculated	Calculated
N2	1	0.3923	0.7480	0.3832	0.5124
CO2	2	71.8831	67.8212	71.9864	1.0614
C1	3	11.7630	14.9654	11.6816	0.7806
C2	4	1.7157	1.7848	1.7140	0.9603
C3	5	1.3147	1.2173	1.3172	1.0820
IC4	6	0.3459	0.2942	0.3472	1.1801
NC4	7	0.9093	0.7365	0.9137	1.2406
IC5	8	0.4261	0.3148	0.4289	1.3626
NC5	9	0.5875	0.4201	0.5917	1.4084
IC6	10	0.4017	0.2551	0.4054	1.5895
NC6	11	0.4549	0.2883	0.4592	1.5927
IC7	12	0.1745	0.1030	0.1763	1.7118
NC7	13	0.9973	0.5462	1.0088	1.8467
IC8	14	0.2616	0.1319	0.2649	2.0086
NC8	15	0.8522	0.4107	0.8635	2.1023
IC9	16	0.2804	0.1270	0.2843	2.2381
NC9	17	0.6802	0.2906	0.6901	2.3750
IC10	18	0.4224	0.1654	0.4289	2.5939
NC10	19	0.2610	0.0991	0.2651	2.6739
C11	20	0.7667	0.2854	0.7789	2.7297
C12	21	0.6555	0.2179	0.6666	3.0590
C13	22	0.5605	0.1642	0.5706	3.4753
C14	23	0.5605	0.1417	0.5712	4.0306
C15	24	0.5906	0.1274	0.6024	4.7278
C16	25	0.4913	0.0867	0.5016	5.7820
C17	26	0.4440	0.0650	0.4536	6.9750
C18	27	0.2710	0.0343	0.2770	8.0779
C19	28	0.3440	0.0399	0.3518	8.8162
FR1	29	0.1987	0.0255	0.2031	7.9582
FR2	30	0.1987	0.0178	0.2033	11.4428
FR3	31	0.1987	0.0130	0.2034	15.6718
FR4	32	0.1987	0.0124	0.2034	16.4483
FR5	33	0.1986	0.0445	0.2025	4.5493
FR6	34	0.1986	8.0045	5.6433E-09	7.0502E-10
Composition Total		100.0000	100.0000	100.0000	

8. SRK EOS, 7 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Soave-Redlich-Kwong (3-Parm) on ZI
Lohrenz-Bray-Clark Viscosity Correlation

Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 256.5866
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	129.8925	55.7325
Z-factor	1.2101	0.6253
Viscosity	0.2388	0.0668
Density KG/M3	672.2118	558.1382
Molar Vol M3/KG-ML	0.1932	0.0999

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.3854	0.7501	0.3777	0.5035
CO2	2	72.3789	68.4586	72.4616	1.0585
C1	3	11.5556	14.8785	11.4855	0.7720
C2	4	1.6855	1.7414	1.6843	0.9672
C3	5	1.2915	1.1707	1.2941	1.1054
IC4	6	0.3398	0.2797	0.3411	1.2193
NC4	7	0.8932	0.6978	0.8974	1.2860
IC5	8	0.4186	0.2948	0.4212	1.4286
NC5	9	0.5771	0.3924	0.5810	1.4808
IC6	10	0.3946	0.2355	0.3980	1.6895
NC6	11	0.4469	0.2662	0.4507	1.6932
IC7	12	0.1714	0.0944	0.1731	1.8327
NC7	13	0.9797	0.4970	0.9899	1.9916
IC8	14	0.2570	0.1189	0.2599	2.1859
NC8	15	0.8372	0.3685	0.8471	2.2989
IC9	16	0.2755	0.1131	0.2789	2.4650
NC9	17	0.6682	0.2571	0.6769	2.6330
IC10	18	0.4149	0.1448	0.4206	2.9055
NC10	19	0.2564	0.0865	0.2600	3.0062
C11	20	0.7532	0.2484	0.7638	3.0752
C12	21	0.6439	0.1871	0.6536	3.4930
C13	22	0.5507	0.1389	0.5593	4.0281
C14	23	0.5507	0.1178	0.5598	4.7531
C15	24	0.5802	0.1039	0.5902	5.6817
C16	25	0.4826	0.0690	0.4913	7.1247
C17	26	0.4361	0.0505	0.4443	8.7992
C18	27	0.2662	0.0261	0.2713	10.3818
C19	28	0.3380	0.0301	0.3445	11.4552
FR1	29	0.1673	0.0165	0.1705	10.3474
FR2	30	0.1673	0.0114	0.1706	15.0298
FR3	31	0.1673	0.0079	0.1707	21.7373
FR4	32	0.1673	0.0059	0.1707	28.9118
FR5	33	0.1672	0.0063	0.1706	26.8684
FR6	34	0.1672	0.0361	0.1700	4.7103
FR7	35	0.1672	8.0983	5.0575E-11	6.2451E-12

Composition Total	100.0000	100.0000	100.0000

9. SW EOS, 4 psudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Pedersen Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 263.3944
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	150.8514	58.0063
Z-factor	3.1766	0.6793
Viscosity	23.3215	0.1347
Density KG/M3	307.7009	553.3194
Molar Vol M3/KG-ML	0.4903	0.1048

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.4954	0.6528	0.4900	0.7506
CO2	2	64.4954	59.4135	64.6674	1.0884
C1	3	14.8537	17.0809	14.7783	0.8652
C2	4	2.1666	2.1427	2.1674	1.0115
C3	5	1.6602	1.4564	1.6670	1.1447
IC4	6	0.4368	0.3594	0.4394	1.2225
NC4	7	1.1482	0.9016	1.1565	1.2827
IC5	8	0.5381	0.3923	0.5430	1.3843
NC5	9	0.7418	0.5260	0.7491	1.4242
IC6	10	0.5072	0.3287	0.5133	1.5614
NC6	11	0.5745	0.3717	0.5813	1.5638
IC7	12	0.2204	0.1346	0.2233	1.6595
NC7	13	1.2594	0.7260	1.2774	1.7596
IC8	14	0.3304	0.1782	0.3355	1.8824
NC8	15	1.0761	0.5623	1.0935	1.9449
IC9	16	0.3541	0.1764	0.3601	2.0419
NC9	17	0.8589	0.4105	0.8741	2.1296
IC10	18	0.5333	0.2393	0.5433	2.2701
NC10	19	0.3296	0.1447	0.3358	2.3202
C11	20	0.9681	0.4200	0.9867	2.3495
C12	21	0.8277	0.3313	0.8445	2.5493
C13	22	0.7078	0.2597	0.7230	2.7838
C14	23	0.7078	0.2353	0.7238	3.0760
C15	24	0.7458	0.2238	0.7635	3.4114
C16	25	0.6204	0.1649	0.6358	3.8558
C17	26	0.5606	0.1338	0.5751	4.2986
C18	27	0.3422	0.0753	0.3513	4.6624
C19	28	0.4344	0.0913	0.4461	4.8878

FR1	29	0.3763	0.0960	0.3857	4.0178
FR2	30	0.3763	0.0869	0.3860	4.4407
FR3	31	0.3763	0.1926	0.3825	1.9854
FR4	32	0.3763	11.4911	2.2961E-06	1.9981E-07
Composition Total		100.0000	100.0000	100.0000	

10. SW EOS, 5 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Aasberg-Petersen Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 253.9175
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	155.3935	58.1959
Z-factor	3.4911	0.6643
Viscosity	1.0365	0.2359
Density KG/M3	274.9698	541.1738
Molar Vol M3/KG-ML	0.5651	0.1075

Molar Distributions Components		Total, Z	Liquid,X	Vapour,Y	K-Values
Mnemonic	Number	Measured	Calculated	Calculated	Calculated
N2	1	0.4860	0.6664	0.4811	0.7220
CO2	2	65.1700	60.4739	65.2953	1.0797
C1	3	14.5715	17.3964	14.4961	0.8333
C2	4	2.1254	2.0889	2.1264	1.0180
C3	5	1.6286	1.3901	1.6350	1.1762
IC4	6	0.4285	0.3371	0.4309	1.2783
NC4	7	1.1264	0.8414	1.1340	1.3478
IC5	8	0.5278	0.3601	0.5323	1.4783
NC5	9	0.7277	0.4808	0.7343	1.5273
IC6	10	0.4976	0.2955	0.5030	1.7019
NC6	11	0.5636	0.3341	0.5697	1.7049
IC7	12	0.2162	0.1197	0.2188	1.8278
NC7	13	1.2354	0.6388	1.2513	1.9588
IC8	14	0.3241	0.1548	0.3286	2.1230
NC8	15	1.0557	0.4849	1.0709	2.2088
IC9	16	0.3474	0.1505	0.3526	2.3428
NC9	17	0.8426	0.3470	0.8559	2.4664
IC10	18	0.5232	0.1993	0.5319	2.6681
NC10	19	0.3233	0.1199	0.3287	2.7412
C11	20	0.9497	0.3469	0.9658	2.7841
C12	21	0.8120	0.2683	0.8265	3.0800
C13	22	0.6944	0.2059	0.7074	3.4361
C14	23	0.6944	0.1819	0.7081	3.8917

C15	24	0.7316	0.1684	0.7467	4.4344
C16	25	0.6086	0.1197	0.6216	5.1943
C17	26	0.5500	0.0939	0.5622	5.9886
C18	27	0.3357	0.0515	0.3433	6.6705
C19	28	0.4262	0.0614	0.4359	7.1037
FR1	29	0.2953	0.0516	0.3018	5.8506
FR2	30	0.2953	0.0398	0.3021	7.5991
FR3	31	0.2953	0.0392	0.3021	7.7019
FR4	32	0.2953	0.1332	0.2996	2.2500
FR5	33	0.2953	11.3587	1.6453E-08	1.4485E-09
Composition Total		100.0000	100.0000	100.0000	

11. SW EOS, 6 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Pedersen Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 249.9948
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	161.2517	58.2971
Z-factor	0.2428	0.6612
Viscosity	137.1123	0.1383
Density KG/M3	4019.4116	533.6869
Molar Vol M3/KG-ML	0.0401	0.1092

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.4788	0.6782	0.4745	0.6997
CO2	2	65.6799	61.2068	65.7767	1.0747
C1	3	14.3582	17.4668	14.2909	0.8182
C2	4	2.0943	2.0441	2.0954	1.0251
C3	5	1.6048	1.3359	1.6106	1.2056
IC4	6	0.4222	0.3192	0.4245	1.3299
NC4	7	1.1099	0.7931	1.1167	1.4081
IC5	8	0.5201	0.3347	0.5241	1.5661
NC5	9	0.7171	0.4453	0.7230	1.6236
IC6	10	0.4903	0.2699	0.4951	1.8343
NC6	11	0.5553	0.3051	0.5607	1.8381
IC7	12	0.2130	0.1083	0.2153	1.9878
NC7	13	1.2173	0.5728	1.2313	2.1495
IC8	14	0.3193	0.1372	0.3233	2.3559
NC8	15	1.0402	0.4273	1.0535	2.4654
IC9	16	0.3423	0.1315	0.3469	2.6380
NC9	17	0.8303	0.3007	0.8417	2.7996

IC10	18	0.5155	0.1706	0.5230	3.0665
NC10	19	0.3186	0.1022	0.3233	3.1645
C11	20	0.9358	0.2947	0.9497	3.2222
C12	21	0.8001	0.2242	0.8126	3.6241
C13	22	0.6842	0.1689	0.6954	4.1175
C14	23	0.6842	0.1461	0.6959	4.7628
C15	24	0.7209	0.1321	0.7337	5.5534
C16	25	0.5997	0.0911	0.6107	6.7060
C17	26	0.5419	0.0694	0.5522	7.9557
C18	27	0.3308	0.0372	0.3372	9.0645
C19	28	0.4199	0.0438	0.4281	9.7832
FR1	29	0.2425	0.0304	0.2471	8.1232
FR2	30	0.2425	0.0221	0.2473	11.1793
FR3	31	0.2425	0.0175	0.2474	14.1403
FR4	32	0.2425	0.0197	0.2473	12.5739
FR5	33	0.2424	0.1116	0.2452	2.1979
FR6	34	0.2424	11.4418	6.6255E-11	5.7907E-12
Composition Total		100.0000	100.0000	100.0000	

12. SW EOS, 7 pseudocomponents:

Expt MCMP1 : Multiple Contact Miscibility Calculation
Peng-Robinson (SchWen) on ZI with PR corr.
Aasberg-Petersen Viscosity Correlation
Specified temperature Deg K 377.5500
Vapourising drive injection gas G13
Multiple contact miscibility pressure BARSA 250.1958
(to 1 atmosphere accuracy)

Fluid properties	Liquid Calculated	Vapour Calculated
Mole Weight	170.1469	58.5234
Z-factor	0.5497	0.6682
Viscosity	0.6931	0.2414
Density KG/M3	1875.2723	530.6408
Molar Vol M3/KG-ML	0.0907	0.1103

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
N2	1	0.4789	0.6995	0.4750	0.6790
CO2	2	65.6756	61.3849	65.7522	1.0711
C1	3	14.3600	17.4817	14.3043	0.8182
C2	4	2.0945	2.0267	2.0958	1.0341
C3	5	1.6050	1.3015	1.6104	1.2374
IC4	6	0.4223	0.3065	0.4244	1.3844
NC4	7	1.1100	0.7584	1.1163	1.4720
IC5	8	0.5202	0.3157	0.5238	1.6591
NC5	9	0.7172	0.4186	0.7225	1.7260
IC6	10	0.4904	0.2503	0.4947	1.9761

NC6	11	0.5554	0.2829	0.5602	1.9805
IC7	12	0.2130	0.0996	0.2151	2.1600
NC7	13	1.2175	0.5220	1.2299	2.3562
IC8	14	0.3194	0.1237	0.3229	2.6102
NC8	15	1.0404	0.3830	1.0521	2.7470
IC9	16	0.3423	0.1169	0.3464	2.9640
NC9	17	0.8304	0.2652	0.8405	3.1695
IC10	18	0.5156	0.1486	0.5222	3.5132
NC10	19	0.3186	0.0886	0.3227	3.6409
C11	20	0.9360	0.2551	0.9481	3.7162
C12	21	0.8002	0.1910	0.8111	4.2458
C13	22	0.6843	0.1414	0.6940	4.9079
C14	23	0.6843	0.1199	0.6944	5.7914
C15	24	0.7210	0.1061	0.7320	6.9012
C16	25	0.5997	0.0710	0.6092	8.5753
C17	26	0.5420	0.0527	0.5507	10.4498
C18	27	0.3309	0.0277	0.3363	12.1609
C19	28	0.4200	0.0321	0.4269	13.2901
FR1	29	0.2079	0.0187	0.2113	11.2718
FR2	30	0.2079	0.0133	0.2114	15.8853
FR3	31	0.2079	0.0097	0.2115	21.7641
FR4	32	0.2079	0.0081	0.2115	26.1171
FR5	33	0.2078	0.0109	0.2113	19.4455
FR6	34	0.2078	0.1149	0.2094	1.8224
FR7	35	0.2078	11.8530	1.0909E-13	9.2036E-15
Composition Total		100.0000	100.0000	100.0000	